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SILICON CHIP

NOVEMBER 2014
ISSN 1030-2662
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Ref: Silicon Chip Magazine March 2004

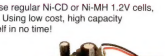
This great little converter allows you to use regular Ni-CD or Ni-MH 1.2V cells, or alkaline 1.5V cells for 9V applications. Using low cost, high capacity rechargeable cells, the kit will pay for itself in no time!

- PCB: 59 x 29mm

KC-5391

Kit supplied with PCB, and all electronic components.

$15.95



12/24VDC 20A Motor Speed Controller Kit

Ref: Silicon Chip Magazine June 2011

Control the speed of 12 or 24VDC motors from zero to full power, up to 20A. Features optional soft start, adjustable pulse frequency to reduce motor noise, and low battery protection. The speed is set using the onboard trimpot, or by using an external potentiometer (available separately, use RP-3510 $2.25).

- PCB: 106 x 60mm

KC-5502

Kit supplied with PCB, and all electronic components.

$39.95

High Energy Ignition Kit

Ref: Silicon Chip Magazine Nov & Dec 2012

Use this kit to replace a failed ignition module. Suits vehicles with ignition system that use a single coil with points, hall effect/lumenition, reluctor or optical sensors (Crane and Piranha) and ECU.

- PCB: 98 x 56mm

KC-5513

Kit supplied with silk-screened PCB, diecast enclosure, pre-programmed PIC and PCB mount components for four trigger/pickup options. Hall-effect and optical pick-ups not included.

$49.95

GPS Data Logger/Tracker Kit

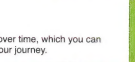
Ref: Silicon Chip Magazine November 2013

Precisely records where your car or boat has travelled over time, which you can playback on software such as Google™ Earth to map your journey.

- Records onto an SD card (available separately)
- Records point-of-interest at the touch of a button
- 12VDC powered
- PCB: 142 x 74mm

KC-5525

$149



Kit supplied with silk-screened PCB, enclosure with label, pre-programmed PIC, GPS module, and electronic components. The SMD components are already pre-soldered to the PCB to save you the hassle.

Jaycar Electronics

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KG-9250

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Kit supplied with DMM case, LCD, solder, battery, test leads, PCB, comprehensive 18 page learning manual and electronic components.

Transistor Tester Kit

Ref: Electronics Australia September 1983

Have you ever unsoldered a suspect transistor only to find that it checks OK? You can avoid these troubleshooting hassles with the In-Circuit Transistor, SCR and Diode Tester. The kit does just that, test drives WITHOUT the need to unsolder them from the circuit!

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KA-1119

$27.95

Kit supplied with a Jiffy box, battery and electronic components and panel showing truth table for device checking.

NEW KITS

Mini-D 2 x 10W Class-D Amplifier Kit

Ref: Silicon Chip Magazine September 2014

Can deliver more than 10W per channel or 30W mono. Features on-board volume control, low-power shutdown mode and over-temperature/current protection. Compact design and highly efficient.

- Powered from 8 - 25VDC
- No heatsink required!
- PCB: 85 x 46mm

KC-5530

Kit supplied with double sided, solder-masked and screen-printed PCB, and ALL SMD components pre-soldered to the PCB.

$49.95

Potato Clock Kit

You can generate enough electricity to run a digital clock by plugging electrodes into common potatoes! Also works with tomatoes, lemons, apples - even soft drink or beer!

- Clock size: 65(W) x 30(H) x 12(D)mm
- Recommended for ages 10+

KJ-8937

$9.95

Kit supplied with highly accurate digital clock module, metal electrodes with wire, instructions and fluid beakers. Potatoes not included. Fruit/veg not to be consumed after use.

Household & Security Kits

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This kit operates the included relay based on preset temperatures. Ideal as a thermostat, ice alarm, or hydroponics applications, etc. Adjustable temperature range of -30° to +150°C.

- 12VDC powered, use MP-3147 $17.95 (sold separately)
- PCB: 56 x 28mm

KG-9140

Kit supplied with PCB, NTC thermocouple and all electronic components.

$24.95

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Let your CCD camera see in the dark! This infrared light is powered from any 12-14VDC source and uses 32 x infrared LEDs to illuminate an area of up to 5-metres (will vary with light conditions). PCB draws a current of about 300mA.

- Suitable plugpack supply, MP-3282 $14.95 (sold separately)
- PCB: 74 x 55mm

Note: Not suitable for colour CMOS cameras.

KG-9068

$29.95

Kit supplied with silkscreened/ gold plated/ solder-masked PCB, 32 x infrared LEDs and all electronic components.

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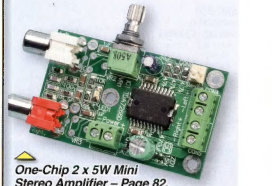

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- 150mm length

~~$19.80~~ **$15** P365

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~~$19.80~~ **$15** P367

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RPC-C/4	4"	823 Kgf	R9711	$8.90
RPC-C/6	6"	953 Kgf	R9712	$9.90

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- 17 Piece
- 10 - 42mm

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- 39.5 - 81mm

~~$60.50~~ **$49** P031

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~~$42.90~~	~~$19.80~~	~~$63.90~~	~~$24.20~~
$36	**$16**	**$45**	**$20**
P350	P351	P354	P355

Offset Fabricated Vice
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- 152mm jaw width

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STEEL

Standard Drill Press Vices

100mm	127mm	152mm
~~$22.00~~	~~$27.50~~	~~$33.00~~
$18.70	**$23**	**$28**
V124	V125	V126

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C86-5S - Short Series
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- Double cut burrs
- SD-3, SD-5, SG-5, SC-5, SF-5
- 1/4" x 6" shank

C86-5S	C86-5L
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$69	**$79**
B900	B905

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- 4 x screw on flute countersinks
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- 1 x HSS blade
- 1 x pocket clip

~~$49.50~~ **$39** D082

Deburring Tool Set
- Includes: 2 holders, sheet metal holder, 10 pack HSS blades, 20mm countersick blade, 2 x scraper blades, "V" & inverted "V" scraper, 4 telescopic extensions & wrenches

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23 PIECE

Bench Vices
- Acme screw thread
- Fitted width serrated jaws

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100mm	127mm	152mm
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$55	**$87**	**$120**
V088	V089	V090

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- HSS M2 bright finish

25 Piece Metric (D1272)
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- 1 /64" increments

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~~$90.20~~ $69 D1282

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- 12.7mm round

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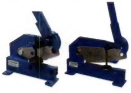

Metric Thread Repair Kit

- M5 x 0.8mm
- M6 x 1.0mm
- M8 x 1.25mm
- M10 x 1.5mm
- M10 x 1.75mm

~~$163.90~~ $139 T100

130 PIECE

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- HSS precision ground flutes
- Ø1.0 - Ø10mm
- 10 drills each size up to 8mm then 5 per size

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EDBD-13 Drill Sharpener

- 3-13mm or 1/8"-1/2"
- Split point
- 80W 240V motor

~~$99.00~~ $79 D070

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- HSS M2 bright finish
- Industrial quality

~~$36.50~~ $32 D508

HSS

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- 4-12 x 1mm
- 6-20 x 2mm
- 6-30 x 2mm

~~$77.00~~ $59 D1071

HSS

PP-13C Precision Drill Sharpener

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- Portable on wheels
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- 3/4" & 1" square
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- Includes light

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- 16 spindle speeds
- Swivel & tilt table
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2MT SPINDLE

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SPD-20B Pedestal Drill
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Drilling Machines

- 20mm drill capacity
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- Swivel & tilt table
- 1hp, 240V motor
- Includes light

2MT SPINDLE

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SPD-25A Pedestal Drill
~~$429.00~~ $385 D147

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- Quick change gearbox
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- 0.55kW, 240V motor

~~$1,265.00~~ $1,155 L160

Shown with optional stand

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- Quick action gearbox
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~~$1,815.00~~ $1,595 L149

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26mm BORE

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Publisher's Letter

An amplifier to warm the cockles of your heart

Doubtless we will have again divided the readers of SILICON CHIP with a controversial article this month. Some will love the Currawong valve amplifier presented in these pages (with more articles to come) and some will inevitably see it as a pointless exercise and so "last century". Even some of those readers who are keen on valve amplifiers will doubtless find something to criticise, such as the fact that it has negative feedback, or not enough feedback, or not enough power from the tetrodes, or whatever.

For our part, we see it is another interesting design exercise, whether it is based on thermionic or solid state devices. Indeed, we have used a mixture, with valves being used for the signal path, to give that all-important "valve sound" and with solid-state devices used in the power supply and infrared remote control. We don't think too many potential builders will be put off by the fact that it has an infrared remote volume control though; quite the opposite.

As with any design exercise, there are compromises on many aspects. If cost was no problem, we could have produced an amplifier with a lot more power and possibly a little less distortion. But we have to be realistic, knowing that a sky-high cost will make the unit unattractive to the vast majority of readers who might like to build a modern valve amplifier.

Of course, the over-riding reason why we have designed and presented the Currawong amplifier is that we realise that there is considerable interest in valve amplifiers and "valve sound", even if we do believe that the best solid-state amplifiers are far superior to any valve design. A quick look at the performance graphs on pages 33, 37 & 38 will show that is the case, on the raw figures. Our Tiny Tim amplifier (SILICON CHIP, October & December 2013, January 2014) is a better performer and much cheaper to build.

For valve aficionados though, raw figures are of little interest. Indeed, Allan Linton-Smith, one the proponents of the Currawong, demonstrated an early hard-wired prototype together with our 15W Class-A Stereo Amplifier to an interested group and he reported that most people present preferred the sound of the valve unit. Heresy! Cynically, I just think it can't have been a very good demo; if I had done it, the preferences would have been entirely the other way! Well, OK, maybe not entirely the other way.

Of course, much of the attraction of valve amplifiers relates to the fact that they are inherently simpler technology and for many people they are nostalgic – a throwback to simpler past. Solid-state amplifiers don't glow in the dark, do they? Much the same can be said of the resurgence in interest in vinyl records and turntables. In many ways, there is more satisfaction in selecting a record to play, reading the sleeve notes, putting the disc on the turntable and then very gently placing the stylus of the cartridge into the lead-in groove – and then it begins to play. By contrast, playing a CD or pressing a button to select a digital sound track is a cold and impersonal process.

So there is considerable attraction in old technology and that is why we finally decided to do the work involved in presenting the Currawong. It has not been an easy task to produce it. So even if you regard valve amplifiers as an anachronism and out of place in a magazine called SILICON CHIP, have a read through the article this month and those to come. It is a most interesting exercise and one which makes us realise that those designers from so many decades ago really did achieve very good results with such simple technology.

Leo Simpson

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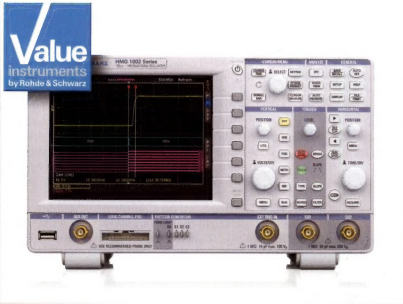

The competition ends on December 8th 2014, hurry to enter for your chance to win.

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Don't meddle with the switchboard Earth-Neutral connection

The article on the MEN system used in domestic wiring in the August 2014 edition was very good reading. It took me back to when I was an apprentice electrician in the UK.

We were on a job when the tradesman sent me to connect an electric drill into the local fuse board (there were no battery drills in the late 1950s). On inspection I found that there was no Neutral, so he told me to connect the Neutral to the Earth. When he checked what I had done, he told me where I had gone wrong. I had twisted the Earth and Neutral wires together and then bolted them to Earth. The way I had done it was very dangerous because if the connection I had made to Earth had come off, using the drill would have been fatal, with the frame of the drill being at 240VAC and looking for a return.

What I should have done was connect the Earth and the Neutral via different bolts. That lesson from all those years ago brings me to the MEN system and seeing how dangerous it can be. The thought of domestic homes still working apparently as normal without a Neutral would have to be ringing alarm bells in high places. With the homes still working in this way, it goes without saying that the main Earth (homes built before 1973 only having one Earth point) will fail at some stage. When this happens, all appliances with any metal will become live. The only safe appliances would be those that are double-insulated.

A simple procedure to check this would be to remove the link between the Neutral and Earth bus-bars. If things stop working you can assume that the Neutral connection has failed. It would be interesting to see how many homes are affected. So in the interest of safety maybe the link should be left off; as an added bonus, how many plumbers would be saved? The MEN system may have benefits for the supplier like the Neutral not being 24VAC above earth (would that kill anyone?) but at what cost?

I congratulate you on an excellent article. It certainly made me think about things and it really is a shame that only your readers get to see it.

Tom Pawson,
Mount Warrigal, NSW.

Editor's note: we must warn against anyone disconnecting the link between Neutral and Earth. That is a task which must only be done by a licensed electrician. Anyone else meddling with it may cause a lethal situation.

Wideband RF probe design critique

Wide bandwidth scope probes have long been a special interest of mine so I found the Active Differential Probe for Oscilloscopes by Jim Rowe, (SILICON CHIP, September 2014) interesting. I like the idea of the LED at the tip. Also there is a handy application note from Keysight (ex-Agilent) on Eight Hints for Better Scope Probing at **http://cp.literature.agilent.com/litweb/pdf/5989-7894EN.pdf**

GPS car navigation can be illogical

I must say I had a laugh at the Publisher's Letter in the October 2014 issue, on the topic of GPS navigation. I also have a few thoughts on the matter. I finally bought a GPS about five years ago and the only street directory I now have is a 1922 copy which might have some monetary value. One would think picking the quickest route via GPS from Penrith to the airport would be via the M4, the M7 and the M5 but nothing I select will stop it heading off down Mamre Road to Elizabeth Drive and taking the country route.

I actually ran the demo of the selected route first time through and was amazed that the airport had apparently been moved to North Shore Crematorium, a place with which I am very familiar! Anyhow, a bit of checking of street names quickly confirmed my thoughts that there was a street named after an aviator at both the airport and the crematorium. So now, if I want to go to the airport, I set the GPS, travel down the M4, M7 and M5 and SHMBO awakes along the M5 to announce that I should "stay in the left lane and prepare for a left turn ahead".

That's fine by me. I now simply drive off in the direction of wherever I may be headed and leave the final destination to the GPS and the lap of the gods.

On the other hand, I was up at the Sunshine Coast in early December last year to pick up a secondhand car and was met at the airport by the seller. All well and good. He drove to the nearest registry office and once we had completed all the documentation and I gave him the remaining $500 in cash, I set the GPS to the address of my uncle whom I hadn't seen since 1996. All went well until "take the next left and you have reached your destination".

OK, it looked a bit like an RSL retirement village but upon getting out and walking around, things seemed just a bit too quiet. I rang him on my mobile phone and one of my cousins was on the line to ask me for a few landmarks. After exchanging details, she finally told me I should have turned right – sound familiar?

I backtracked and was there five minutes later to be met by my cousin waving to me from the front door of the village unit – a happy ending!

Alan Greaves,
St Clair, NSW.

The circuit is not very complex and it is easy to understand but I am puzzled by a few things. There is no obvious attempt to compensate the probe in 10:1 mode, so I'm wondering how you manage to keep the frequency response within +0.2dB/-0.3dB (~2.5% to ~3.5%) to 40MHz. Serendipity?

Of course it could well be that the PCB and components provide exactly enough parasitic capacitance that the probe is perfectly compensated on the 10:1 range but what about device variations? I guesstimate that the FET contributes about 1pF of input capacitance (the data sheet is not very explicit). A 10% change in device capacitance (we're talking about 0.1pF) between devices would cause a wrinkle of about 0.3dB in the frequency response on the 10:1 range and could wreak havoc with the common mode rejection of the probe (depending on circumstances).

I suspect that the exact orientation of the FETs on the PCB and even the amount of solder used might have a measurable effect on the frequency response on the 10:1 range, with subsequent impacts on CMR and dynamic range.

Similar issues apply to the 3MΩ resistors that provide the low frequency attenuation on the 10:1 range. It is worth noting that the resistors provide the attenuation only for frequencies below 100kHz.

In the specification panel "Maximum AC voltage input before overload, both probe tips" is given as 2V peak-peak. The meaning of that is not clear. My initial interpretation was that it meant both inputs have the same overload level but I think what is really meant is that the maximum common mode AC voltage is 2V. In either case, that requires that one or two amplifiers would have to deliver 4V peak-peak before overload.

The data sheet for the AD8038 says that the output swing with 5V supply and a 2kΩ load is 0.9V to 4.1V (ie, 3.2V peak-peak). In fact, on page 11 of the data sheet Fig.40 (Output Swing vs Load Resistance) shows output swing is less than 0.5V peak-peak with a 5V supply and 100Ω load (the load on IC3 with the recommended 50-ohm termination).

That suggests that the maximum output voltage of the probe would not reach 250mV peak-to-peak or a peak value of little more than 100mV, taking into consideration the attenuation of the 50-ohm termination resistors. Leaving off the 50-ohm termination at the oscilloscope would allow much greater output at low frequencies but one metre of 50-ohm coax is likely to restrict the bandwidth to less than 40MHz, which implies that the frequency response would be down 1dB at 20MHz and there would be significant phase shift and time delay associated with it.

The data sheet for the AD8038 gives the slew rate as 425V/µs (typical), which gives a maximum output of 4V peak-peak for frequencies below 34MHz before slew rate limiting starts to distort the waveform. So the "Maximum AC voltage input before overload" would apply only for frequencies below 34MHz and should be derated linearly for frequencies above that.

The quiescent output voltage of the probe is set by the V_{GS} of the FETs and the data-sheet for the BSS83 gives the threshold value of V_{GS} as between 0.1V and 2V. If by chance the $V_{GS(thresh)}$ of one FET was 1V then the output of the probe is likely to be nearly saturated

Copper thieves vandalised the MEN system

In the August 2014 edition of your wonderful periodical I read with great interest the article about the MEN system. I was aware of this system and the potential issues (pun intended) associated with faults and oversights when dealing with the Earth side aspects of this system from my early days of helping an electrician friend. It was great to see it put into a simple and straightforward explanation.

It also reminded me of an event that occurred in my area not so long ago. Some individual or individuals had removed many of the copper earthing wires from the utility poles in the area, presumably for the scrap value of the copper. Upon alerting the local power supplier they immediately sent out crews to rectify the situation. One can only hope that the perpetrator(s) got more than a little tingle for their foolish efforts.

Mark Veraart,
Perth, WA.

Mailbag: continued

Cars with keyless entry can lock you out

Kyle Cogan, in his letter "Keyless car entry & flat batteries" (page 6, October 2014) raises an important point: modern cars that rely solely on an electronic key for entry are at risk when the vehicle's battery goes flat.

I wish to relate the following story to help readers, should they be caught in this predicament. We had the above situation occur some years ago when my wife's Mercedes 4WD developed a flat battery, after the lights had been left on.

Ordinarily this would not be a problem as the vehicle was designed with a fail-safe mechanical key entry at the driver's door. In this instance, the lock had previously broken and we had not yet had it fixed under warranty. The lights had been left on and the battery was so flat that the electric locks would not actuate. There was seemingly no way in.

My wife called our local motorist's association and they kindly offered to come and break a window for her! What was needed was access to the battery. There was no way to open the bonnet. Guards under the engine prevented access from below (although one could hardly reach from below anyway).

All the wiring was inaccessible other than at one point: the light over the number plate! Disassembling this, I used a jumper lead (fitted with battery clips at one end and alligator clips at the other) to connect a spare 12V lead-acid battery to the light terminals (after using a multimeter to check for polarity). I then pressed the key on the hand-held remote every second or so until the door locks opened. It took about three to four seconds.

I figured there was a risk of blowing the light fuse doing this, so as soon the door locks opened, I removed the jumper leads. Note that this technique will only work if the lights have been left on (otherwise the number plate light would not have been connected to the battery).

John Goswell,
Keinbah, NSW.

Comment: it seems as though modern cars need an external charge point to allow the battery to be topped up, to cope with instances like yours.

so the available output swing will be quite small. Adjustment of the FETs' bias voltages could remedy that although there is no provision for it.

Now I am not saying that the probe doesn't work; it probably does. However, it is curious that the bandwidth specification does not cite an output level for the figures quoted; in fact output levels do not appear in the specifications panel at all.

No CMR figure for the probe is given, and the "Maximum AC voltage input before overload" specification seems at odds with the AD8038 data sheet. If the data sheets are to be believed (and generally data sheets are accurate in what they report), then the probe's performance is remarkable. But I feel that any other probe, built as described, from a random selection of parts, is likely to be struggling to meet the specifications published except in somewhat narrowly defined circumstances not indicated in the specifications.

I think some elaboration of the specifications is warranted.

Phil Denniss,
Darlington, NSW.

Jim Rowe comments: you are quite correct in suggesting that with our prototype probes the stray capacitance associated with the range selector switch and the PCB happened to provide just enough compensation on the 10:1 range. We had planned to use a pair of small capacitors wired directly across the switch contacts, if additional compensation proved to be necessary but this did not eventuate.

Of course, if constructors do find that additional capacitance is necessary, it can be added in this way – perhaps as a pair of sub-picofarad 'gimmick' capacitors. However, note that obtaining exactly the optimum capacitance can be a tedious and repetitive process for such small (sub-picofarad) values. But in fact, we would expect that the variation in FET capacitance would be very tight and that has proved to be the case.

Thank you for your analysis of the limitations of the probe with regard to its output level before overload. Presumably, we were also "lucky" with regard to the characteristics of the BSS83 and AD8038 devices used in our prototypes. The main factor limiting the output level is our decision to run the probe from +5V (via a USB port) for user convenience. Using batteries to provide higher supply rails would no doubt improve the performance as far as overload is concerned but that would have required a much bulkier design.

In fact, we don't do our designs from a "random selection of parts". We had to build a number of prototypes to prove the concept and tried a number of different circuit configurations and component combinations before settling on the final design. The design process for developing such a device can also be very frustrating, as we go through a number of PCBs which have to be rejected for various reasons.

By the way, we have found that manufacturers' data sheets should only be used as an initial guide for component selection, particularly for op amps. Sometimes devices perform better than the data sheets would indicate but often it is the other way, with performance not coming up to expectations.

Indeed, manufacturers' application notes can often lead one up the garden path and we have wondered if some circuits have even been tried! Indeed, from bitter experience, we have come to regard some application notes as marketing material rather than engineering information.

To conclude, anyone designing a device solely on the basis of manufacturers' data sheets and application notes is likely to be quite disillusioned with the result. Nor it is necessarily true that one can define a design's drawbacks by poring through data sheets.

Navigation in the days before Omega

When I bought the September 2014 issue, I was intrigued that the cover stated that Omega was "Global Navigation before GPS". The Astrolabe, Sextant, Greenwich Mean Time and

Solar panels for hot water

I was interested in the letter from D. S., on page 99 of the September 2014 issue of SILICON CHIP. I previously tried this approach unsuccessfully. I had solar panels in series giving approximately 180V open-circuit and 125V with 5.7A into the 24-ohm, 2400W element, thus heating at about 700W. The voltage, of course, varies with the angle of the Sun (time of day and time of year). Light cloud drops the voltage by half and the power by one quarter but given all day to heat the water, it worked well.

The problem was the controller. The electric hot water system has a controller, with a thermostat to disconnect the voltage when the water is up to temperature and a cut-out to prevent the HWS turning into a steam bomb if the thermostat fails. The controller in my HWS was rated to switch 30A at 240VAC.

When attempting to break 5A at 120V (DC), the thermostat melted into a short circuit blob. After further heating, the cut-out operated, though damaged by arcing to the extent that it could not be reset.

I have now given in to conformity and bought an inverter, so the HWS, with its new controller, runs off 240VAC buffered by the grid. With privatised power companies continuing to up their prices and the cost of solar panels falling, a SILICON CHIP "50-400V DC input 50Hz output" inverter project would be popular with readers wanting cheaper hot water.

John Burns,
Beverley, WA.

Comment: a simpler approach may be possible: using the existing HWS thermostat to control a power Mosfet which could easily switch off the DC current and voltages involved. That would still leave the potential issue of corrosion due to DC on the tank element.

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the Almanac, Norry's and other sight reduction tables and NAVSAT obviously have been forgotten. The article did say "global real-time radio navigation before GPS."

When I used NAVSAT (TRANSIT), compared to a sextant, I thought I was in real time because the set could be "programmed" to run in "deduced (dead) reckoning (DR)" until the next satellite fix. A sextant fix could be as good as a five nautical mile radius. A NAVSAT fix could be as good as one nautical mile radius; sometimes better if the satellite was 10° above the horizon (60 minutes = 1 degree of latitude; 1 minute = 1 nautical mile; 1nm x 1.8 = 1 kilometre – approximately). Usually there were six satellites a day.

In the early 1980s, I crewed, as the sail-maker, on a yacht that was in the Marina del Rey, California, to Puerto Vallarta, Mexico, Yacht Race. It covered 1000 nautical miles south along the Mexican Baja Coast. The owner of the yacht had bought an Omega set and special charts overprinted with Omega grid lines to use in the race. We weren't aware that the grid lines were a specific distance apart and anyway, their distance varied depending on one's distance from the antenna. The set gave us four numbers that we had to plot for our position. The owner didn't buy a NAVSAT set because of a reputation of unreliability.

I remember the owner running a DR plot, on the chart, while he read the numbers of the Lines of Position from the set. He also did a Noon Sight, with his sextant, to confirm his DR. Interpolation, of the Omega LOPs, was so complicated that the "computer geek" quickly read the manual and helped out.

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Mailbag: continued

Nostalgia for valve sound

The letter by Brian Collath in the September 2014 issue, perpetuating the "valves are better than transistors" myth, reminded me of two amusing stories.

Since about 1970, I've had and loved Tannoy loudspeakers but although they are terrific, nothing is perfect and from time to time, I get an urge to buy something better. Although I explore the competition, I usually just end up with another pair of more modern Tannoys.

During the 1980s, I visited a local hifi shop asking to audition some loudspeakers. The audition was an enjoyable experience, filling me with a mysterious warm inner glow that I couldn't explain immediately.

When the sales person returned, he asked, "How did you like the amplifier?" "Amplifier? Um . . . I've come to audition loudspeakers." As he explained that he'd used an outrageously expensive valve amplifier, the explanation of the mysterious warm inner glow became obvious. I was enjoying the nostalgia of remembering the distortion of the radiograms my parents owned during my childhood.

More recently, I and a few friends began taking an elderly friend to jazz concerts because he likes jazz and we hoped to cheer him up. Although he'd thank us politely after each concert, he'd also offend us a bit by complaining that the sound was terrible and the players couldn't play and . . . He'd also bought a quite good mini hifi system that sounded jolly terrific to me but he complained about that as well.

It had tone controls on the front, so I suggested that he might like to use those to make it sound better. Ah. He preferred full bass and treble cut, but still complained. I eventually realised that his "benchmark of perfection" was not modern CD or even old black vinyl but really old 78 RPM black shellac. I made him a special box with IN and OUT connections and a really crummy circuit giving even more bass and treble cut inside. I didn't bother to create fake noise. He loved it; just like the real thing. He thinks I'm a genius.

Keith Anderson,
Kingston, Tas.

Although I am not "geeky", I was enlisted to ponder the meaning of the LOPs on my watch when I was not steering. Our DR plot sort of agreed with the Omega set (definitely more accurate than a sextant). Between the three of us, we were convinced Omega was the "dawn of the new age" if we could only figure out the meaning of the LOPs.

When we were about 500 nautical miles into the race, the Omega set became unreliable, giving erroneous LOPs on the other side of the world, and we lost reception of some of the LOPs. We eventually turned the set off. The owner continued the yacht race with his sextant. He relied on my superior night vision when we neared the coast at the end of the race (I could see the surf breaking on the shore!).

Later, I made many ocean crossings using my sextant. On one voyage from Hawaii to Tahiti, an owner had a NAVSAT set. After a few days into the voyage, I put my sextant into its box and relied on the NAVSAT and charts to make landfall.

As the 1980s progressed, yacht races began to accept the reliance on NAVSAT and later, GPS. When GPS began, NAVSAT disappeared because it wasn't all that accurate (especially inaccurate when the chart survey datum did not agree with the NAVSAT datum). I remember one race, north to Mooloolaba from Sydney, where yacht positions were given on the beach. This phenomenon continued until chart datum was upgraded to GPS datum.

A major problem with GPS, in the early days, was the threat of unreliability during a military conflict, as was experienced during the Gulf War. Another problem was that one had to buy the military model if one wanted to be very accurate (to the square metre).

With the advent of GPS, I'm surprised that Omega lasted so long. Now, with chart plotters, the demand for charts is diminishing. I am in a minority because I have a chart collection, use dividers, run a DR, know how to change magnetic bearings to true bearings on the chart, and do not call charts "maps."

Marshall Miller,
Manly, Qld.

Alcohol breath analysis is a fraught process

I am writing to draw attention to new Victorian legislation making the fact that one over-the-limit drink driving prosecution is enough to cause a loss of licence and resultant job loss in many cases. Also, a $1400 interlock device is then required to be fitted after one indiscretion. See this news item regarding the interlock devices: www.abc.net.au/news/2014-10-01/vic-drink-drivers-forced-to-install-alcohol-interlock-devices/5781552

This is not good enough, with the technology being inadequate to generate legal measurement results. Most speed camera equipment is also not required to pass proper scientific testing, as the testing officer only has to be satisfied as to their accuracy. This is not scientific and should be classed as illegal but the "authorities" are getting away with it.

After I won my 67km/h speeding case on similar issues, the same strategy was used to win on appeal on 20th October, 2011 in the Victorian County Court, in the case of Agar v Baker, heard by Judge Allen. It goes to show you don't need a legal qualification, just determination and the correct facts.

While I generally applaud the use of alcohol interlock devices in cars, the problem of accuracy of breath testing machines must be questioned. Some reports (from America, of course) which were never properly questioned, said that these machines were 2.3% accurate while a different scientific finding discovered they had moved the decimal point from 23.0% to 2.3% accuracy. Other tests revealed inaccuracies up to 48%.

Findings in a scientific peer-reviewed paper revealed this fact and it was never challenged as untrue. The court finding held. It is for this reason we should understand that many technological devices are being

misrepresented as being accurate and are further attacks by those in power on the motoring public.

Furthermore, I might mention that now anyone who makes the mistake of over-indulging even slightly can lose their license, job and family due to no income. This is most unjust and this law must be rescinded. Are our politicians completely devoid of knowledge and sympathy? Or is this another attack by those who see CO_2 and motor cars as polluting and would rather have bicycles on the road?

Reference: http://blog.motorists.org/its-just-a-decimal-point-the-dirty-secret-behind-breathalyzers/

John Vance,
Wangaratta, Vic.

Comment: we asked food technologist and designer of the Alscolyser alcohol analyser (SILICON CHIP, November 2013) Allan Linton-Smith to comment:

With over 40 years experience of food and beverage analysis, there is one thing I know for a fact: it is really difficult to analyse alcohol accurately. Some of the methods used for analysing ethanol in liquids include density, gas chromatography, IR spectrum analysis and fuel cell detection (such as in the SILICON CHIP Alscolyser). Each has drawbacks, essentially because of interference with other materials and contaminants such as sugars, petroleum spirits, adhesives, solvents etc.

"Breathalysers" in general make the assumption that human breath is a fixed fraction of the blood alcohol content (BAC). Typically, they are calibrated on a calculation that BAC is between 2000:1 and 2300:1 – see www.lionlaboratories.com/testing-for-alcohol/the-lion-units-converter/

This conversion factor can vary enormously especially between men and women, small and large people, with levels of hydration and food in the stomach! This allows even bigger errors to creep in!

I would go even further to say that breath testing inaccuracies are there for 99% of the time! But remember to drink responsibly at all times – if you want to argue against a driving infringement then get the best lawyer you can. But that won't save any lives!

In one state in the USA, everyone

More comment on unsafe products purchased on-line

I read Barrie Davis' comments in the October 2014 issue regarding potentially unsafe wiring on several imported 10W LED floodlights. I too had purchased a light from overseas and this prompted me to check it out.

Earth? What earth? I realised with dismay that the unit only had a two parallel pin plug with no earth whatsoever when used with an adaptor. And the internal design was just as Barrie described and potentially just as dangerous.

While I could replace the power cable and earth this device effectively, I am suspicious of the safety of the small LED driver (which was unsealed on my unit). It has certainly made me think again about buying electrical devices from overseas.

Thank you Barrie.

Brenton Brockhouse,
Felixstow, SA.

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Mailbag: continued

Terra-Terra – an alternative to MEN?

That was a very interesting article in your August edition about the potential hazards of the MEN mains system. It was also quite timely in that coincidentally this topic was raised just recently as part of my electrical re-certification training. In fact, there is a proposal here in New Zealand to change from the MEN system to the TT system (Terra-Terra) because of the very reasons outlined in your article, and because many building switchboards now have RCD protection installed which is a fundamental requirement of the TT system.

In the TT system, the Neutral is still earthed at the supply transformer but the Earth-Neutral link at the switchboard is removed and RCDs then provide all the protection. So the only thing that the earthed metal framework of every the class 1 appliance is connected to is the stake in the ground.

In this configuration, should a fault occur where a live conductor comes into contact with any earthed part of the appliance, instead of a short circuit current tripping an over-current breaker, an earth "fault current" flows with the resulting current imbalance tripping the RCD.

So the end result (from the user's perspective) is the same as with the MEN system; the "breaker" trips but without the typical bang, sparks and resultant scorching. I had never heard of the TT system until fairly recently but upon learning about it, I think that the concept of separating the load current circuit from the protective Earth circuit makes a lot of sense.

It would certainly solve the issue of water pipes potentially becoming live and posing a danger to plumbers etc. I can't think of any drawback apart from the extra cost of an RCD protecting every circuit, including the fixed appliances. If a building already has RCD protection installed then it is certainly a very easy conversion. So I personally think that this would be the way to go in the long term.

Grant Sexton,
Cambridge, NZ.

Comment: we hope to feature an article on the Terra-Terra system in the near future.

was let off the hook because of poor breathalyser calibration technique!

Interlock devices fitted to cars typically prevent a driver from starting the engine at 0.025% (to account for inaccuracies), so if you have one of these, just don't drink anything alcoholic if you plan to drive!

Denying science has a penalty

I subscribe to an "electronics magazine" to have access to factual, informative and interesting information in the field of electronics. Climate science falls well outside an electronics magazine's expert area but regrettably SILICON CHIP magazine continues to espouse misleading, non-

factual and non-scientific responses regarding the topic of human induced global warming.

To deny science is one of the stupidest things a non-scientist can do. To deny science undermines every aspect of a technical magazine. For a technologist or applied scientist to deny science is tantamount to them declaring their "expert" knowledge has no basis in fact.

Based entirely on your ongoing and continuing unscientific responses to the subject of global warming, I shall not be renewing my subscription. The economist Nicholas Stern did warn of the economic consequences of disregarding climate change and that disregard has just cost you $100 per year and an erstwhile loyal reader.

Robert Suhr,
Mt Crosby, Qld.

Comment: we do not deny science; quite the opposite. Scepticism has always been a characteristic of scientists, otherwise new science would never have been developed. More and more information is coming to light which casts a great deal of doubt over the global warming movement.

We have covered this topic because it is very relevant to the drive for renewable energy. Solar energy is desirable but the way it has been promoted and subsidised in Australia is a gross misallocation of resources. Wind power is worse because it requires constant and very expensive back-up, with costly gas-fired open-cycle power stations or with the much despised coal-fired base power stations.

Australia now has an excess of power generating capacity but expensive solar and wind installations are still being heavily subsidised, to the detriment of consumers, taypayers and overall employment.

NBN fibre-to-the node will be less reliable

Living in Kingston, Tasmania, my suburb is in the second set of suburbs scheduled for completion of NBN. The adjoining Kingston Beach was in the first set and from what I have heard, people are extremely pleased with the performance of fibre to their home connections although many had frustrations with the final connection to the house, with time-consuming legal/boundary issues caused by rerouting cables. Over the last two years, work has been in fitful progress to my road; it should have been completed in March 2013 but has been delayed by various stoppages over safety and other more obscure problems.

Finally, with all the asbestos Telecom pits having been replaced by plastic, in June this year my road was ready for individual connections. During this delay, we have had a change of government. In their infinite technical wisdom, they decided to change the game to fibre-to-the-node, a decision I find non-sensical.

In July 2013, I was fortunate to be able attend a lecture by the NBN at the Hobart Amateur Radio Club given by the commercial manager and supported by a senior technical officer. The audience was very impressed with the manager's technical knowledge and enthusiasm beyond her managerial responsibilities. She was equally impressed and totally surprised with audience's collective technical knowledge. The technical officer, who was also a New Zealand Radio Amateur, had warned her but she was

Mailbag: continued

Comments on the MEN system

Your article regarding the MEN system (SILICON CHIP, August 2014) has provoked a lot of interest. It really applies to the way most house installations are wired, including my own, but there are some points to be made about modern practice where plastic piping is used rather than copper.

Firstly, the main earthing conductor connects to the Earth electrode. This has been a requirement since 1976 although installations older than that may not have earth electrodes unless they had alterations since then and had to be updated. The water piping system also connects to the earth bar on the distribution board as do all exposed metal items, involving electrical equipment, in the installation.

AS/NZ 3000 states that the resistance of the main earthing conductor (from the Earth bar to the Earth electrode) shall be 0.5 ohms as a maximum. However, there is no requirement for the Earth electrode to have any minimum resistance at all!

In the case of my home, the electrode had a resistance of 25Ω! However, I have a large copper water piping system, much of it buried, and this is the main safety feature rather than the Earth electrode. With an installation current of over 20A, I checked the current going to the Earth electrode and through the water meter. In both cases, the currents measured were zero on a tong ammeter with a full-scale deflection of 6A (the lowest range available).

In a house with non–metallic piping there would be a much more dangerous situation if the Neutral became disconnected as compared to a house with buried metal piping. You will not get much help from an Earth electrode unless it has a very low resistance to ground. Even a load current of 10A would bring all the earthed items up to full mains voltage in the event of a house with no water piping connection, an open Neutral and an earth electrode with a resistance of 25 ohms (in 2007/08 there were 522 shock incidents caused by poor or faulty Neutrals in NSW).

There is a good case for having a voltage sensing relay connected between the Neutral link and another remote Earth electrode which would disconnect the mains in the event of an open Neutral, maybe via the smart meter.

There is a good article on the above issue titled "Options to Improve the MEN System Into The 21st Century" by Chris Halliday – see **powerlogic.com.au**

Your advice about calling for expert help if you experience even a slight tingle is certainly correct.

Alex Brown,
Ashburton, Vic.

still surprised at the level of technical questioning.

It all made for a lively, highly constructive evening, much enjoyed by both parties. Modules of the fibre-to-home distribution system were available for detailed inspection. For someone whose first job in Australia was at the AWA research labs in North Ryde on mobile communications and experimental fibre optics (yes, Australia could make optical fibre in 1973), this was of a great deal of interest. In 1973, all thoughts for application were for trunk routes and the economical distribution to individual dwellings a problem not fully resolved.

I was therefore intrigued how a delicate elegant principle had evolved into a simple and robust practical individual dwelling distribution system. It was recognised even back in the AWA research labs days that the optical fibre was not going to be the expensive part of a practical installation. The system being used by NBN is a simple light pipe from the substation to home and has no interstage electronics, with "non-precision aligned" plug-in take-offs requiring minimal skills to install.

Intrinsically lightning-proof and rot proof, it is I think the natural system for a future secure communications network. It would seem that two technology advances enabled this simple configuration: first, the advent of high power LEDs (the area of technology I was associated with at AWA); and second, the system of digital coding which seems to be an adaptation of a University of WA's invention in the late eighties called Q.P.S.X, standing for Queued Packet Switching Exchange.

What the current government seems to be trying to save is the costly labour-intensive process of laying the fibre into homes through Telstra pits and sorting out a myriad of historical problems with an outdated and ageing (and in some humid parts of the country, chemically decaying) copper system. Although I suspect there has been some artificial bloating of the workforce for this task, it is probably the most mechanically needed part of the infrastructure upgrade (things don't last for ever).

It is also providing much needed local employment for a reasonable period of time. It's interesting how governments subsidise short term "job creation" most which fail miserably and are penny pinching for needed work on a project of high future national importance.

Apart from the cost of placing an active electronic node at the bottom of the road, the use of the old copper wires is a recipe for short, medium and long term problems. It is the old copper street distribution network which causes the costly maintenance problems! Also, fibre to the home allows for expansion of capacity as technology develops. It is a decision to commit to a hybrid system of the worst kind, a typical short-term decision for immediate financial savings by those who do not understand or want to understand the long-term consequences.

Whether I get fibre to node or home, even though promised for all current works, has become mystery and after three or four notices of pending connection in the last eight months, so is the day of actual connection. Meanwhile and perhaps not surprisingly, we have had hints of another new policy: you can have a choice of fibre to node or to the home but guess what, you will have to pay an as yet undetermined amount for fibre-to-the-home.

Kelvin Jones.
Kingston, Tas. SC

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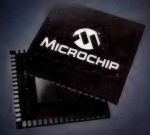

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GORILLA GLASS: unbelievably tough and flexible

Most people know that smart phones and many notebook computers use Gorilla Glass but few would know just how tough or flexible this glass is. Unlike ordinary window glass it can be flexed by extreme amounts and it is very hard. In this article we describe how it is manufactured.

By Dr David Maddison

These days, most people have smart phones or tablet computers but may not be aware of the special material that constitutes the front face of most of these devices.

These devices often receive rough treatment as they are accidentally dropped, sat upon or otherwise abused and so have to be extremely rugged overall – but most of all the cover glass.

It is designed to be thin, tough, optically clear and extremely smooth and is mostly a glass known by the Corning trade name of 'Gorilla Glass'.

While glass materials are generally brittle there are a variety of special treatments available to make them extremely hard or tough.

Examples include lamination of two or more sheets to make automotive windshields or bullet-resistant glass; thermally or chemically-toughened glass as usually used on the side windows of cars and glass tables or doors in homes; and modern glass bottles, some of which will not even always break if dropped on a concrete surface.

In portable electronic devices such as smart phones and tablet computers the marketing emphasis is on how thin a device can be made (even though many would prefer a slightly thicker device with a decent battery life!).

Every single component is made as thin as possible, including the cover glass. Since normal glass is not strong enough in its usual form when it is made to the desired thinness, special compositions and treatment of glass is

needed that makes it both strong and tough as well as thin. Plastic, an obvious candidate material, generally cannot be produced with the look or feel that is found desirable on the working surfaces of smart devices.

Glass composition

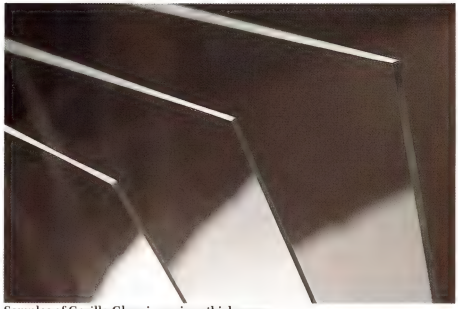
Glass has been manufactured by mankind since around 3500BC where it was produced in Mesopotamia. Before that, natural glass such as volcanic obsidian was used and extensively traded by stone age societies.

Glass, in its most basic form is made from silicon dioxide (silica, SiO_2) or (mostly) beach sand. Unfortunately this is not practical to use for large scale production (except for specialised applications requiring strength and heat resistance) as it melts at a very high temperature (between 1600 and 1725°C).

So other constituents are added which help lower the melting point and also add certain desirable properties.

In most common commercial glasses such as window glass, both limestone (calcium carbonate which is turned into lime, CaO) and sodium carbonate (Na_2CO_3) are added to the silica base along with some other ingredients.

This type of common glass is known as soda-lime-silica glass. It is cheap and useful but not especially strong.

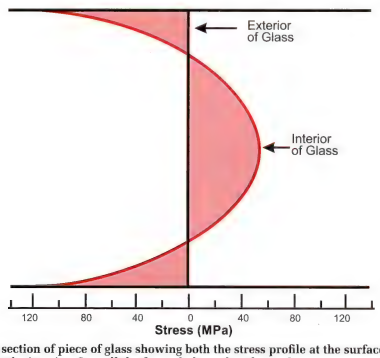


Samples of Gorilla Glass in various thicknesses.

Other common glasses based on silica include sodium borosilicate glass (Pyrex), lead oxide (crystal) glass and aluminosilicate composition (used in fibreglass, halogen light globes and other applications requiring resistance to high temperatures and thermal shock).

Corning uses an aluminosilicate glass for its Gorilla Glass. It is roughly intermediate in properties and cost between a common basic soda-lime-silica glass and the exotic pure silica glass and offers a good mix of properties such as good mechanical properties and workability of the melted glass.

A typical composition for aluminosilicate glass (but not the secret one used in Gorilla Glass) is silica (SiO_2) 57%, alumina (Al_2O_3) 16%, lime (CaO) 10%, magnesia ($MgCO_3$) 7%, barium oxide (BaO) 6% and boric oxide (B_2O_3) 4%.



Cross section of piece of glass showing both the stress profile at the surface and also at the interior. Overall the forces balance but the surface is in compression, meaning that cracks have difficulty starting. The interior is in tension where cracks could easily propagate should they reach that area but they normally don't, due to the surface of the glass being in compression.

How to strengthen the glass

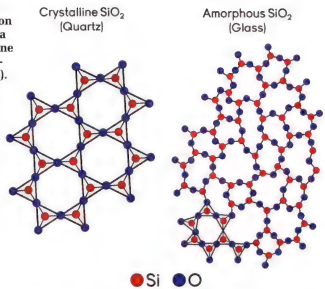
Phone glass has to be tough. One way to turn ordinary brittle glass into a much stronger form is by a special chemical or thermal treatment that puts the surface of the glass in compression compared to the interior of the glass.

In other words, the surface is made to expand and would tend to occupy a greater volume than it formerly did but it is constrained from doing so as it is held back by the bulk of the glass comprising the interior.

The atoms of the surface glass are thus squeezed closer together. This has the effect that it makes it much harder for cracks to initiate or continue to grow should a crack become initiated as the crack edges are being pushed together.

If there is no cracking, there can be no failure of the glass.

In addition to making the initiation or propagation of cracks harder by putting the surface in compression, crack initiation can also be made much more difficult by ensuring the glass surface is extremely smooth, with a minimal



The atomic structure of the same material, silicon dioxide, shown in both a highly ordered crystalline form (quartz) and amorphous form (silica glass). The red dots represent silicon atoms while the blue represent oxygen atoms. Elements of the basic crystalline structure can be seen in the glassy form at a short range but there is also great randomness to the structure at a longer range.

number of microscopic defects that can act as crack initiation centres.

The number of surface defects in glass can be minimised by acid treatments, polishing or by the way the glass is cast. One example is by forming the glass onto a smooth molten metal surface such as tin, as in the case of float glass.

Gorilla glass is made with an extremely smooth surface which not only makes it extremely transparent but makes the image of the underlying display distortion-free. It also makes the glass pleasant to touch and resistant to staining.

Glass technology has continued to improve throughout the ages but particularly from the 20th century until the present as material behaviour came to be understood at the atomic and molecular level. Glass strength in particular has undergone constant improvement.

Thermally toughened glass was first patented in 1900. Laminated glass, which was invented in 1903, was an accidental discovery.

Similarly by accident, in 1953 a Corning scientist discovered a remarkable form of material called a glass-ceramic which they called Pyroceram which found its way into laboratory ware, missile nose cones and microwave oven ware. In 1958, a consumer product was released into the market place which is familiar to most people today – hard-to-break CorningWare dinnerware.

Glass-ceramic materials such as CorningWare are a hybrid between traditional glass and ceramic materials and possess both types of structure. Structurally, glass is said to be amorphous (a pseudo-random structure) while ceramic materials are crystalline (a regular structure). Gorilla Glass is a pure glass with a pseudo-random, amorphous atomic structure.

After the discovery of glass-ceramic, the Corning company started looking at other ways to strengthen glass. It began work with chemically treated toughened glass in the 1960s and developed a product called "Chemcor" as part of its "Project Muscle" initiative to make a glass product that was strong, light and close to unbreakable.

This glass was used in small quantities in some early US "muscle cars" in order to lighten their weight as well as some space craft windows and tableware.

Ultimately this glass was considered too strong for most applications and its use waned. A further concern was the way in which, when it did fail, the glass would explode which was a reason that some safety eyeglasses that used this product were recalled.

The glass fell out of favour as a lightweight material in muscle cars because, despite the weight saving, human head impact forces were found, in experiments, to be much greater on the Chemcor glass compared with laminated glass which had been in use in cars since the 1930s. The latter glass had some "give" thus reducing head injuries.

Project Muscle was shelved in 1971. The Chemcor class of chemically toughened glass products then became a solution in search of a more suitable problem to solve.

ADVANTAGES OF GORLLA GLASS

- Highly scratch resistant.
- Very thin and compatible with touch screen technology.
- Very lightweight.
- Allows thin and lightweight devices without fragility.
- Available thicknesses 0.4 - 2.0 mm.
- Low distortion of underlying image.
- Optically clear.
- Extremely smooth.
- Recyclable.

The 1965 Dodge Coronet A990 muscle car which was specially lightened by a number of modifications, including the removal of some trim and the use of Corning Chemcor glass windows instead of regular glass. It was an early, "hi-tech" consumer-end use of chemically strengthened glass. There is an unexpected connection between this car and the modern smart phone....

The fusion draw process. Two streams of molten glass flow down both sides of a v-shaped trough, rejoin at the base of the v and then solidify. It is a continuous and highly automated process.

Along comes Apple

Then along came Steve Jobs from Apple Inc.

In the various published accounts of how Apple requested a new glass product for the iPhone, certain details seem to vary but the following account is supported in the biography of Steve Jobs by Walter Isaacson and also quotes of Jobs and the Corning CEO in 'Wired' magazine.

Steve Jo bs unveiled the original iPhone to the public on 9th Jan 2007 and it was released on 29th June 2007. For some period before the original unveiling it is said that Steve Jobs had been carrying around an iPhone prototype in his pocket and was upset that the plastic face had become scratched from keys in his pocket.

Presumably the prototype screen face was made of plastic. He ordered his staff to find a solution and time was running out before the release date. He wanted a scratch-resistant glass face on the phone.

In February 2007 Steve Jobs decided to visit Corning in New York where he met with the CEO Wendell Weeks. He told him that he wanted to have tens of thousands of square metres of very thin, ultra-strong and ultra-scratch-resistant glass, a product that did not yet exist and within a seemingly impossible time frame of six months (or less).

According to Walter Isaacson, Steve Jobs said to Wendell Weeks "This is what I want, a glass that can do this". Wendell Weeks said "We once created a type of process that created something called Gorilla Glass". Steve Jobs said "No, no, no. Here's how you make really strong glass". Wendell then said, "Wait a minute, I know how to make glass. Shut up and listen to me". Wendell Weeks then described the process to make Gorilla Glass.

Steve Jobs then said "Fine. In six months I want enough of it to make – whatever it is – a million iPhones". Wendell then said "We don't have the capacity – none of our plantes make the glass now."

Steve Jobs looked at him and said what he said to Steve Wozniak 20 or 30 years earlier: "Don't be afraid, you can do it". Wendell Weeks later told the biographer "I just sat there and looked at the guy. He kept saying, 'Don't be afraid. You can do this.'".

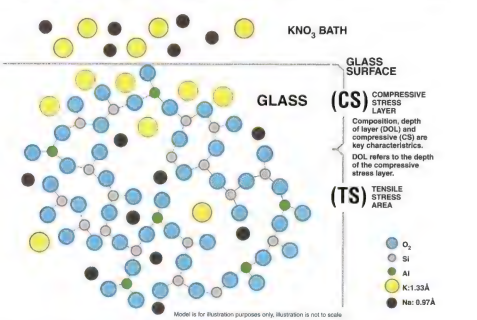
While Chemcor glass would be a good starting point this product was not suitable as it was, because it was made much thicker at around 4mm and Apple's requirement was for glass that was around 1.3mm thin.

It was not known if the Chemcor process could be scaled to make much thinner glass and whether the chemical toughening would work with that thinness and the glass still remain ultra-strong.

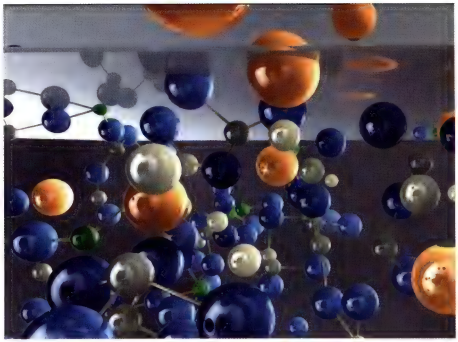
In fact, before Steve Jobs came on the scene with Apple's requirements, in 2005 Corning had already resurrected internal interest in the Chemcor glass, known in-house as 0317.

Motorola had introduced the Razr V3 flip phone which used a glass front screen instead of plastic and Corning wondered if there could be a speciality market for this kind of glass for phones and other small devices like watches.

Such a glass would need to be strong like Chemcor but very thin and smooth. Marketers concluded there



The aluminosilicate glass is placed in a bath of molten potassium nitrate, KNO^3 (common name, saltpetre) and some of the sodium atoms near the surface (grey, 0.97Å in diameter) leave the glass and are replaced by much larger potassium ones (yellow, 1.33Å in diameter). This results in the surface layer being placed in compressive stress and the interior layer in tensile stress. Other elements present in the composition of the glass are oxygen, silicon and aluminium.



Computer model of atomic structure near surface of Gorilla Glass during the ion-exchange process, looking from the inside out. Note the larger yellow potassium atoms entering the surface, which are replacing the smaller grey sodium atoms.

was a demand for glass of this nature but researchers had not got far by the time in February 2007 when Apple started demanding massive quantities of it. Nevertheless, the project to make glass for this speciality market had the codename "Gorilla Glass".

Fortunately, Corning, while it is a big company, thinks like a small company with a can-do attitude.

After the meeting with Steve Jobs, Corning started experimenting with different glass compositions and was coming close to something suitable by the end of March 2007.

Inventing a new manufacturing process and equipment for the glass in the short time frame provided was totally out of the question and Corning had to find ways to adapt existing manufacturing processes and equipment to make the glass.

And it had to be amenable to producing very large amounts of materials for the millions of iPhones expected to be made.

There is only one way to make near-perfect, thin sheets of glass in very large quantities. This is the fusion draw process and it is a proprietary technology that Corning is highly experienced with and a reason for their technological leadership.

It is capable of producing exceptionally flat and smooth uniform-thickness sheets of glass with surfaces that are free of contamination (unlike the float glass process where one surface comes in contact with molten tin).

The fusion draw process was first developed in the 1960s for the production of the aforementioned muscle car windshields, shelved and then reinvigorated for Gorilla Glass.

The process is also used by Asahi Glass Co, Nippon Electric Glass, and Samsung Corning Precision Glass for making thin, large area glass for flat screen display panels.

Fusion draw is a continuous flow process (also known as the overflow down-draw method). Molten glass is continuously loaded into a V-shaped trough and overflows on both sides, runs down the sides and then both flows join together at the bottom of the V to make a continuously moving sheet of glass flowing toward the ground.

As the glass progresses it cools and solidifies. Automated machinery cuts off pieces of the glass and stacks them. As with all well-thought-out processes, it sounds simple but just imagine the massive amount of fine tuning that would have been required to make it work perfectly.

It was critically important to get the composition of the glass just right as it had to melt at a usable temperature, had to have the right viscosity and it had to produce a glass with reasonable optical and mechanical properties as well as being amenable to the chemical toughening process.

This involved juggling the proportions of the six standard ingredients in aluminosilicate glass (see above) as well as a seventh secret ingredient.

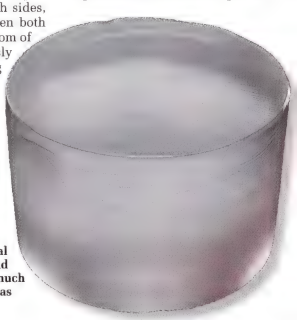
A Corning YouTube video of the process can be seen at **http://youtu.be/q4ZU7zUxdM8** (or search for "The Fusion Process: At the Core of Corning's Glass Innovations" on YouTube).

Once the glass has been cut into sheets and stacked, it is still not Gorilla Glass. It has to be cut and shaped to final size and then surface toughened by an ion-exchange-process.

How is Gorilla Glass toughened?

After the fusion draw process described above the glass is sent to another factory for cutting to final shape and then it is subjected to an ion-exchange process to place the surface of the glass in compressive stress which is the key to the great strength of this glass.

The ion-exchange process involves dipping the glass in a molten bath of potassium nitrate for a period of



A 38cm diameter sapphire "boule" from GT Advanced Technologies. To make cover glass for smart devices pieces have to be sliced off with a diamond saw or using a laser process. Sapphire is a potential competitor to Gorilla Glass and is more scratch-resistant but much more expensive and not quite as transparent.

time. This causes the small sodium atoms to leave the surface regions of the glass while larger potassium ions enter the glass.

Gorilla Glass itself is made in the USA but it is sent to a factory in China for final cutting and toughening.

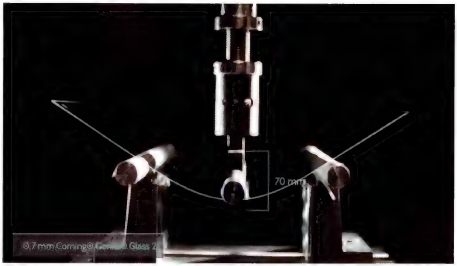
The iPhone 6 – Gorilla Glass or Sapphire Crystal?

Apple has never stated what it uses for the cover glass in its various smart products but it is certain that Gorilla Glass was used for the iPhone 1 and it is widely believed that Gorilla Glass is what it uses for all other past and current models of iPhones and iPads.

There was recently much speculation as to whether the iPhone 6 would use Gorilla Glass or sapphire crystal as its front glass but it has now been established that the main display glass is not sapphire.

Sapphire crystal (aluminium oxide, α-Al_2O_3) is used as the "glass" on high end watches now because of its high hardness and therefore scratch resistance but in that application it is relatively thick and heavy.

Sapphire crystal is many times more expensive, 1.6 times heavier and requires 100 times more energy to produce than glass and it is not quite as transparent as Gorilla Glass.



Gorilla Glass is strong (but not indestructible). Here a 0.7mm thick sample of Gorilla Glass 2 is subject to a 70mm deflection in a three point bending test.

Due to its higher refractive index, sapphire has been claimed to be more reflective than Gorilla Glass. Also, because it is not quite as transparent as Gorilla Glass, the underlying display would need to be brighter and thus more energy-consuming.

While it is more scratch-resistant than glass, sapphire does still break. In terms of scratch resistance, sapphire has a hardness of 9 on Mohs scale compared with 10 for diamond and around 7 for Gorilla Glass 3.

Nevertheless, Gorilla Glass is not likely to scratch in normal use.

The iPhone 5 already uses sapphire for the camera lens cover and the 5S also uses it for the fingerprint scanner. Speculation that Apple may use sapphire for the display in the iPhone 6 arises from its deal with GT Advanced Technologies to supply sapphire materials but these may currently be just for the camera lens and fingerprint scanner (should one be installed) or other products such as the Apple Watch.

GT Advanced Technologies certainly has the capability to make very large crystals or "boules" (single crystal synthetic ingots) of sapphire for special applications as shown in the illustration of a piece that is 38cm in diameter.

Ultimately, it is thought that Apple did not proceed with sapphire for the main screen on the iPhone 6 because of both supply and cost. GT Technologies was thought not to be capable of ramping up production of flawless large pieces of crystal for an estimated 80 million iPhone 6s.

Sapphire will be used on the Apple Watch which will have a much smaller display (38mm or 42mm depending on model) than the phone.

Testing Gorilla Glass in the laboratory to measure mechanical properties.

Gorilla Glass is not unbreakable

Some people have interpreted the great strength of Gorilla Glass to mean that the product is unbreakable.

Nothing is unbreakable and it is certainly true that sometimes the Gorilla Glass of smart phones and tablets does break if the devices are dropped onto concrete or other hard surface.

There are numerous "tests" people

have done that can be viewed on YouTube in which the outcome is that the glass either does not break under the challenge or it does.

What is impressive is the significant amount of abuse that the glass will usually take before it finally breaks. It is interesting that people are prepared to sacrifice their perfectly good phones for these demonstrations.

Like any advanced electronic devices phones and tablets have to be treated with respect.

As part of their ongoing quality procedures, Corning obtains whatever phones it can with failed Gorilla Glass and examines the failure mode and tries to see how such failure modes can be avoided.

Future development

Apart from smart phones, tablet and slate computers Gorilla Glass is being increasingly used in notebook computers, as a large cover glass on large scale interactive digital displays, digital signage and marker boards.

In interior architecture, designers are exploring the possibilities of making entire walls with Gorilla Glass.

Other emerging applications will rely upon glass properties such as it being sleek, cool to the touch and readily cleanable, possessing exceptional damage resistance and being compatible with touch screen technologies. It can also be printed on if necessary.

Other anticipated developments include different surface treatments to make the surface antimicrobial (already unveiled), less reflective and less susceptible to fingerprints.

Companion products

Corning has also developed companion materials for Gorilla Glass:

Willow glass is a flexible borosilicate glass for display substrates. It will allow the use of flexible, printed displays.

Delivered on a roll like newsprint, it is anticipated that the display elements will be printed onto the glass akin to a newspaper printing operation. In roll form the glass can be up to 1.3m wide by 300m long and in sheet form it can be up to 1.1 by 1.2m and 0.1 to 0.2mm thick.

Lotus glass is designed as a substrate for OLED and next-generation LCD displays. It is to be used as a display backplane in conjunction with Gorilla Glass for cover material.

MILESTONES IN THE DEVELOPMENT OF GORILLA GLASS

- Billions of devices have now been produced that utilise Gorilla Glass. Since the release of Gorilla Glass 1 in 2007 it has been used on 2,400 different models of smart devices, over 33 brands.
- Gorilla Glass 2 was released in 2012 and achieved a 20 percent reduction in thickness compared with the previous formulation while keeping its damage resistance, toughness and scratch resistance. The reduction of thickness allowed thinner devices with greater touch sensitivity and brighter images.
- Gorilla Glass 3 was released in January 2013 with a feature known as Native Damage Resistance. It is up to 40% more scratch resistant and three times more damage resistant than Gorilla Glass 2. To achieve this the glass was reformulated and extensive atomic-scale computer modelling was undertaken.
- In July 2013 Corning introduced Gorilla Glass NBT for touch screens on notebook computers. The glass provides improved scratch resistance, reduced scratch visibility and better retained strength when a scratch does develop. According to Corning's marketing materials this glass avoids a common form of damage that happens when a notebook computer screen is closed and there is something on the keyboard such as a pen or USB drive, which causes the screen to break.
- Antimicrobial Gorilla Glass has now been developed and unveiled and incorporates ionic silver, which renders the surface of the device anti-microbial for the life of the device.

Conclusion

At no time in history have materials scientists understood more about the behaviour of materials in terms of their atomic and molecular structures. In addition, never has the ability to do computer modelling of materials been greater than now.

This enables scientists and engineers to develop materials with properties that were not conceivable even decades ago. Gorilla Glass is but one example of a highly engineered material that improves our technological progress and makes our daily lives so much easier.

There will be many more materials like it. SC

Another of the many stringent tests Gorilla Glass is subjected to in the laboratory.

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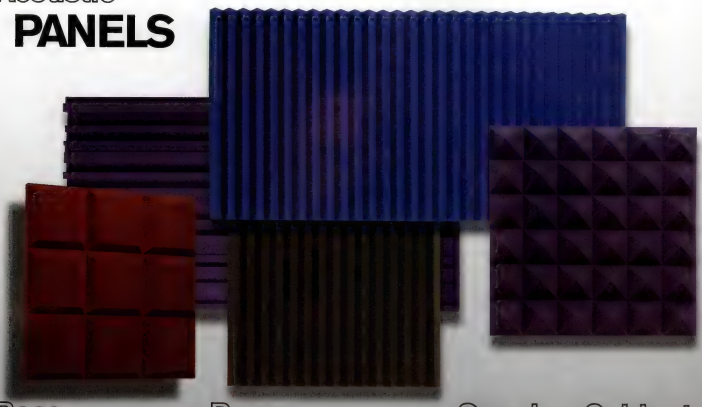

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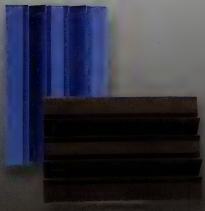

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Watch Free-to-Air TV on your Smartphone, Tablet or Laptop

By ROSS TESTER

The photo above is not a wide-screen TV set – though it is showing a wide-screen free-to-air TV image. It's actually a still image on an Android laptop, showing a televised World Cup match in real time!

The internet is a wonderful, powerful thing. Just think of the things it lets you do every day as a matter or course, which you never would have dreamed of, say ten years ago.

But there is another, seldom-thought-of benefit of the internet: it has in fact spawned the development of a plethora of equipment to use this power – again, equipment which was only the often outlandish musings of science fiction writers of a decade earlier or so.

Take Smartphones, for example. These amazingly powerful computers (for that's what they are) often relegate the 'phone' function to a distant second place.

It's all about apps (applications for you Luddites!) which turn your Smartphone into, well, anything you want.

Now there's TV on the move

Add a tiny USB dongle to your Smartphone and you're able to watch free-to-air digital TV services wherever you are – without using either your phone service or even a broadband connection.

We should add that Australian TV services are now all-digital, with analog TV now permanently off the air.

And perhaps we should also add that we are talking here about Android phones. Despite all the marketing hype, Android holds about 70% of the Smartphone market (and its still growing). Apple users – don't despair: there are similar services available for

you. But they're not what we are talking about here.

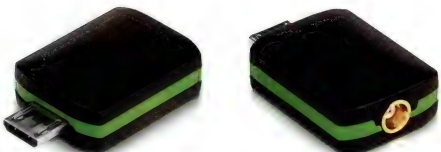
Back to the Android Smartphone and TV. Recently, Altronics sent us one of their 'PadTV' packs to try out. Their Director, Brian Sorensen, waxed lyrical on the 'phone about how amazing the tiny dongle was. And now we know why!

The PAD TV Tuner dongle

You almost feel cheated when you look at the dongle. It's not much bigger than your thumbnail. Yet within this tiny device is all the 'smarts' to turn your Android (4.1 or higher) device into a very high performance TV and even a DVR.

Think about that for a minute: virtually a complete TV tuner in a package that's MUCH smaller than the remote control for your home TV! Of course, it doesn't get anywhere without the computer power of your Smartphone or tablet but you carry that in your pocket anyway.

Now you can take TV wherever you want it – obviously, assuming there is a TV station to pick up. Whether that's camping out, on a boat, at a sportsground, in a car (maybe!), at work (sorry, boss – it's research. . .), you name it – mobile TV at its finest.



Shown significantly oversize for clarity, the front of the PAD TV tuner has a micro-USB plug to mate with your Android Smartphone, Phablet or Tablet, while the rear has a SSMB connector to take one of the supplied mini antennas. An SSMB-to-TV antenna adaptor is also supplied to connect to an outside antenna.

Now before you take those locations/situations as gospel, we should point out that there are limitations.

The most obvious is that there must be a good strength TV signal. That's not just a function of the dongle and its tiny antenna (though naturally, that does have a major influence), it's also a function of digital TV with its 'digital cliff'.

You either have a picture, or you don't – there's no in-between snowy half-picture like there was with analog.

TV reception in a car is also a bit hit-and-miss for much the same reason, added to the fact that the moving car is likely to be in and out of good signal areas, between city buildings, behind hills or mountains, even a large dense tree can interfere with reception.

So while it might be tempting to keep the kids amused on a long trip with the PAD TV, it's probably best to have some DVDs or games available as well!

Another limitation is the size of the screen on your device. It might seem pretty cool to watch TV on a 3.5-inch phone but the lack of detail is less than satisfying. Seeing any horse in the

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Melbourne Cup is difficult; identifying it by number or even jockey colours is near impossible! That's where the larger screens of today's phones, phablets and tablets really makes a difference.

Using it

Unfortunately, it's not simply a matter of plugging in and playing (or viewing in this case). First, you need to download the appropriate app. As an Android device, you would log on to Google Play and search for Pad TV. And here is where you might find the first (and often insurmountable) hurdle.

Remember a moment ago we mentioned that you needed to have Android 4.1 or higher. For the latest Smartphones and tablets, that shouldn't be a problem.

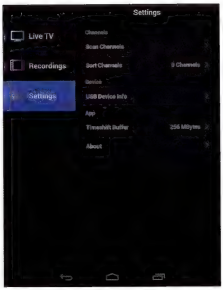
Check it by going to 'settings', thence 'about phone' and scroll down to 'software information'. If it doesn't say 'Android version 4.1' (or higher), you're out of luck. Yes, some phones can be updated but unless your manufacturer has the appropriate patches, you're on your own.

Your Smartphone or tablet must also support USB On-The-Go, or USB OTG. This is a specification and standard that allows USB devices such as digital audio players or mobile phones to act as a host allowing a USB flash drive, mouse, or keyboard to be attached. Most devices now do (especially those with Android 4.1+) but it's worth checking your specs.

Tied up with this is another potential sticking point – the USB port itself. The micro USB male plug on the PAD TV dongle needs to mate with a USB Micro female socket (also known as, respectively, type B and type A).

Fortunately, these days most Smartphones have that micro USB type B port we mentioned earlier. That means the PAD TV dongle will plug straight in.

But it's not always the case.



Once the app is downloaded and installed, setup is straightforward, logical and quick.

There are (currently) four types of USB ports: the 'standard' type A male and female, the smaller type B male and female, the Mini-A, the Mini-B and finally the Micro-A and Micro-B. As their name implies, the micro USB ports are the smallest. There is a combined Micro-A and Micro-B socket which is designed to allow USB OTG, as mentioned earlier.

Incidentally, despite countless millions in use, Mini-A and Mini-B USB sockets are now regarded as obsolete.

Unfortunately, tablets often have only standard or mini USB ports (or perhaps even a proprietary data connector). You might be able to find an adaptor (did your Tablet come with one?) but if you can't connect the PAD TV, you're out of luck . . . again.

We found female micro USB adaptors almost impossible to buy. Note that we did say *almost*! We eventually found one on ebay for the unbelievable price of $2.39 (including postage from China!).

Here are the two antennas supplied – the small loop antenna shown plugged into the PADTV Tuner (above) and the small whip antenna on a base, as seen at left. Just be aware that small antennas such as these don't pick up a whole lot of signal so you need to be in a strong signal area.

Assuming you don't have either wrong version Android or wrong port problems, search for the PAD TV app in Google Play, download it and install it.

The first one we found was a freebie; there may be others offering more facilities but we didn't bother to go further.

And if you can't find PAD TV?

We mentioned earlier that the PAD TV dongle requires Android 4.1 or higher to operate.

If you cannot find PAD TV when you log onto Google Play and search for it, the chances are your Smartphone is not Android 4.1 – Android is clever enough to only show those apps that will operate with the Android iteration on your Smartphone. (Go to Google Play from Windows, for example, and you'll see all that are available).

Setting up

Once the app is installed, when you plug in the PAD TV dongle, the app will automatically find it and load it.

Then you need to set it up. First, you will need to select the appropriate country from the 'settings' menu then scan for available channels. This takes a few minutes, particularly if you're in an area with lots of TV signals.

Here's where you might discover one or more of those wrinkles we mentioned earlier. Our first scan, indoors (wet brick walls), discovered 16 channels but no ABC, 7 or 10.

And when we tried to view any of them, they all said 'No Signal'.

Our second scan was outside and this yielded 60 channels, including multiple ABCs, 7s, 9s, 10s, Gems, etc etc. However, not all worked – again, many said 'No Signal'. But the ones that did work ranged from patchy to excellent.

Obviously the PAD TV was picking up translators from here, there and everywhere – but most didn't have enough power to give us a picture.

You can sort the channels into the order you want them by selecting 'sort channels' and dragging the three horizontal bars on the right side of the listings and dropping them into position.

It would make sense to place the unusable channels at the back of the queue (so far, we haven't worked out

how to delete them but there must be a way!)

Antenna adaptor plug

If you can't find any channels, or if you can't get a picture on any that are found, Altronics include an SSMB-to-PAL adaptor which allows you to plug the PAD TV dongle into your home TV antenna.

Assuming you have a reliable picture on your home TV, this is a proof-of-operation which will allow you to go through the above steps and make sure it's all working for you.

Of course, reverting to the tiny loop or whip antennas might not give you any joy but at least you'll know that it does work with your Smartphone.

The phone's ringing!

And speaking of your Smartphone, what happens if you are watching TV and someone calls you? No problem – the phone becomes a . . . phone! (It reverts to TV when the call is over).

Power

While we haven't measured it, we would imagine that watching TV on your Smartphone would be fairly hungry on the battery.

In fact, the PAD TV dongle itself gets fairly warm with continual use, suggesting that it is dragging a bit of power.

So if you need your phone to be always available for phone calls, that's something to keep in mind. We noticed the battery level symbol had dropped down a couple of notches in the time we were ~~playing~~ researching.

Obviously, you can't plug in a charger while watching TV as they both use the same Micro USB socket.

The verdict?

Even at significantly higher price, we would rate the PAD TV dongle as a bargain.

Of course, there's plenty of apps around to let you stream live TV to your device (want to watch TV from outer Mongolia?) but all these cost you bandwidth – and significant bandwidth at that.

On a limited plan, that's going to cost you plenty.

Not so the PAD TV. Because it receives its signal off-air, there is no bandwidth overhead once you've downloaded the PAD TV app (about 16MB). So, with the proviso that you must be in a good signal area, you can watch TV on your Smartphone wherever you go.

We love it!

Where from, how much?

The PAD TV Digital TV for Android Phones package (dongle, loop antenna, tiny whip antenna and PAL-SSMB adaptor) costs just $69.95 and is available from any Altronics store, reseller of via their website (**www.altronics.com.au**). Cat no is D2800. SC

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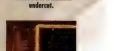

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The Currawo

2 x 10W Stereo Valve Amp

The Currawong amplifier is a tried and tested valve amplifier circuit which has been adapted to components which are readily available in 2014. Each channel uses two 12AX7 twin triodes for the preamp and phase splitter stages and two 6L6 beam power tetrodes in the class-AB ultra-linear output stage. It performs very well, with low distortion and noise.

This progress view of the amplifier shows it sitting in its timber plinth but without the protective Perspex covers in place to protect the PCB and protect the user from high voltages.

By Nicholas Vinen

ong

fier, Pt.1

- 10W per channel
- Low distortion
- Good performance
- Easy to build

IN DESIGNING this amplifier, we wanted to present a unit which is straightforward to build and which has a good appearance. To satisfy the first requirement, most of the circuitry, with the exception of the power transformers, is mounted on a large double-sided PCB. Hence there is no need for point-to-point wiring from valve sockets, tag-strips, tag-boards or any of that stuff from 60 years ago.

Using the large PCB also means that we have avoided the need for an expensive metal chassis. Instead, the PCB slides into a timber plinth stained as rosewood (although you can have any timber finish you desire). As a nice finishing touch, most of the PCB will be covered and protected by a Perspex cover. This will prevent little fingers from touching any part of the circuit and remove any risk of electric shock which would otherwise be possible. We hope you will like the appearance.

There are two toroidal power transformers used to power the Currawong and these are concealed underneath the PCB, towards the back of the unit.

Control panel

At the front of the timber plinth, there is a small control panel suspended below the main PCB. This carries the volume control, the on/off switch, a bi-colour red/green LED, a blue LED and the headphone socket. And while it might seem like a waste to use the Currawong Stereo Valve Amplifier to drive headphones, we know from long experience that readers will definitely want this feature.

By the way, the red/green LED comes into play when you first turn the amplifier on. There is an initial delay while the valves heat up and during this time, no HT (high tension or high voltage) is applied to the plates of the valves which could otherwise suffer damage in the long term. So during this delay, the LED is red. Then, when the HT is applied, the LED changes colour to green, indicating that normal operation is possible.

The other LED is lit when the headphones are in use. Plugging into the headphone socket enables a relay which disconnects the loudspeakers and connects the headphones via 220Ω resistors.

At the rear of the timber plinth is another panel which accommodates the RCA input sockets, the binding post terminals for the loudspeakers and a fused IEC socket for the mains cord. Both the front and rear panels are made from PCB material to provide a high-quality finish.

The overall performance is summarised in an accompanying panel and three graphs. It gives very good performance for a valve amplifier.

Circuit concept

A major difficulty in the design of the Currawong has involved the output transformers. As valve aficionados will be aware, the output transformer is usually the most expensive component in the circuit, apart from the valves themselves. Similarly, these days the power transformer is also very expensive, simply because there is no locally available off-the-shelf unit which can be pressed into service.

Yes, you can purchase imported power and output transformers but if we had specified these, the total cost of the amplifier would have been a great deal higher. Instead, we have taken a very unusual approach in selecting the output transformer by employing a standard off-the-shelf 15W line transformer (Altronics M1115) which would normally be employed with a professional solid-state PA amplifier to drive 100V lines.

As a line driver, the transformer's primary winding is driven by a solid-state amplifier and it steps up the voltage in its multi-tapped secondary winding. In the Currawong though, we drive the transformers back to front, with the push-pull valve output stages driving the 100V windings and the primary windings becoming the low-impedance drive for the loudspeakers. Conveniently, the 100V winding has a centre-tap, which is necessary for push-pull operation. In addition, we use some of the other taps for the "ultra-linear" connection.

Make no mistake though; while these are low-cost transformers (being made in large quantities), they have grain-oriented steel cores, a wide frequency response and low harmonic distortion. Better still, the taps on the primary winding enable it to be connected for ultra-linear push-pull operation. On the other hand, selection of this transformer is one of the two limiting factors in the maximum output power of the Currawong, at close to 10 watts per channel.

The other factor is the power transformer selection. We would have ide-

Features & Specifications

- **Channels:** 2 (stereo)
- **Valve line-up:** 4 x 12AX7 twin triodes, 4 x 6L6 beam power tetrodes
- **HT supply:** ~310V, actively filtered
- **Tested load impedances:** 4Ω, 6Ω, 8Ω
- **Output power:** 2 x 10W (8Ω, 6Ω), 2 x 9W (4Ω) (see Fig.3)
- **Operating mode:** Class-A (8Ω), Class-A/AB (6Ω, 4Ω)
- **Input sensitivity:** ~1V RMS (8Ω, with feedback enabled)
- **Signal-to-noise ratio:** 77dB
- **Channel separation:** >60dB, 20Hz-20kHz (4Ω, 6Ω & 8Ω)
- **Harmonic distortion:** typically <0.1%, 6Ω & 8Ω (see Figs.3&4)
- **Frequency response:** ±0.6dB, 30Hz-20kHz (see Fig.5)
- **Damping factor:** >20 (8Ω), >10 (4Ω)
- **Mains power draw:** typically 120-130W
- **Other features:** ultra-linear outputs, remote volume control option, delayed HT, HT soft-start
- **Dimensions:** 294 x 304 x 186mm (W x D x H) including protrusions

ally liked to use a transformer with much higher secondary voltages but a specially-designed power transformer would be much larger and more expensive, as already noted. Having said that, there is future potential for this amplifier to be upgraded with better (more expensive) transformers to enable it to deliver substantially more output power.

The valves can be replaced without any disassembly. Their sockets are mechanically mounted to the thick (2mm) PCB to prevent the solder joints from breaking loose during valve removal or insertion. The thick PCB also helps to support the relatively high weight of the output transformers, which are mounted on the board for ease of construction.

Temperature-sensitive components such as electrolytic capacitors have been kept away from the high-dissipation components, primarily the 6L6 valves and associated 5W cathode resistors. However, due to the compact size we have not been 100% successful; one of the large filter capacitors is near the output valves. Checks of its temperature during extended operation show that direct heat transfer is minimal and should not be a problem.

Semiconductors

There are some semiconductor components in this circuit but not in the audio signal path. Mostly, these perform power supply filtering, to get rid of ripple and keep the amplifier quiet. The HT delay and soft-start circuit is also built using solid-state components.

We should acknowledge considerable input to the design of this amplifier from Allan Linton-Smith, the designer of the Majestic loudspeaker system featured in the June and September 2014 issues. Allan built the first hard-wired prototype and the concept was then considerably refined and transferred to the final PCB featured in these pages.

Allan also suggested using the Altronics line transformers, based on a discovery by Grant Wills that they could be used as cheap and effective ultra-linear valve output transformers – see **http://home.alphalink.com.au/~cambie/6AN8amp/Grant_Wills_6CM5amp.htm**

Circuit description

Fig.1 only shows the circuit for the left channel signal path. The right channel is identical and the corresponding component numbers are provided in blue.

The line-level input signal from RCA socket CON1 has a 1MΩ DC bias resistor to ground, in case the signal source is floating. The signal then passes through an RF-rejecting low-pass filter comprising a 120Ω series resistor and 100pF ceramic capacitor.

The signal is then AC-coupled to (nominally) 20kΩ logarithmic volume-control potentiometer VR1 by a 1.5µF MKT capacitor. This gives a -3dB low-end roll-off at 5Hz. Note that depending on part availability, a motorised potentiometer with a value as low as 5kΩ may be used, in which case the -3dB point rises to 21Hz.

The wiper terminal of VR1 is connected to ground via a 1MΩ resistor so that if it briefly goes open circuit during volume changes, the grid of V1a does not float. The signal is fed to this grid via a 22kΩ RF stopper resistor.

V1a and V1b form the preamplifier, which is very similar to Jim Rowe's design from the February 2004 issue of SILICON CHIP ("Using The Valve Preamp In A HiFi System"). Essentially, this consists of two common cathode amplifier stages in series, with negative feedback around both.

V1's plates are fed from a filtered HT rail of around 224V DC, somewhat less than the 308V DC main HT rail due to voltage drops across the two RC filter resistors (6.8kΩ and 47kΩ). These filters reduce coupling between channels, reduce coupling from the output stage to the preamp stages and minimise supply ripple reaching the preamp. The preamp is the most noise-sensitive section as the signal level is lowest here.

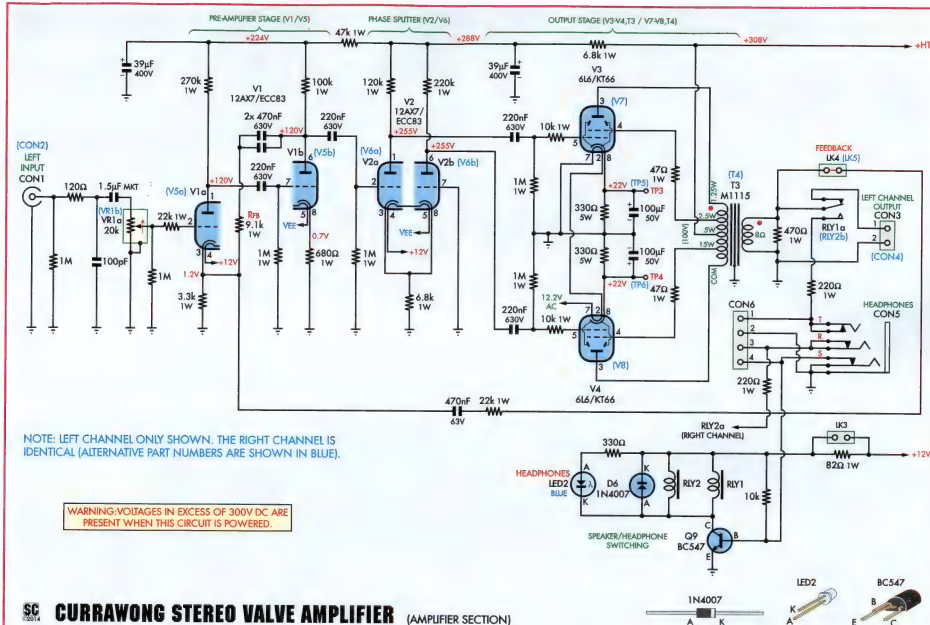
In fact, because hum can be picked up from AC-powered heater filaments, we are running the 12AX7 filaments from regulated 12V DC.

Self biasing

All valves in the circuit are self-biased. V1a's anode runs at around 120V, ie, 224V minus the drop across the 270kΩ resistor. With zero bias, a 12AX7 will conduct around 3mA at this voltage, dropping to near-zero with a grid-cathode bias of around -2.2V. With a 3.3kΩ cathode resistor, V1a's operating point tends to settle at about 0.3mA and thus the cathode is 1.2V above ground.

The output signal from V1a's anode is coupled to V1b's grid by a 220nF capacitor and this grid is DC biased using a 1MΩ resistor to ground. V1b runs at a higher power than V1a, with a 680Ω cathode resistor giving an operating current of around 1mA. Therefore, its anode load resistance is lower at 100kΩ.

The output at V1b's plate is coupled back to V1a's cathode via a pair of parallel 470nF polyester capacitors

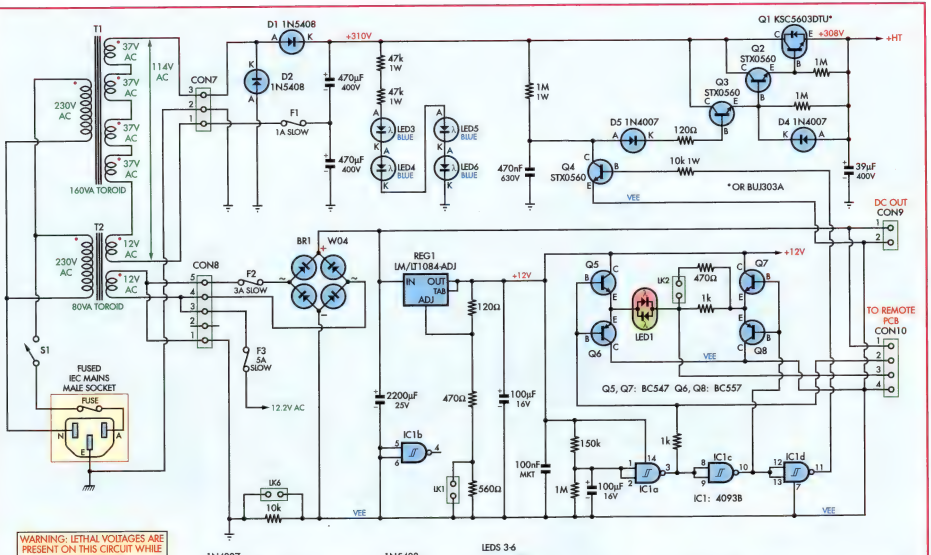


NOTE: LEFT CHANNEL ONLY SHOWN. THE RIGHT CHANNEL IS IDENTICAL (ALTERNATIVE PART NUMBERS ARE SHOWN IN BLUE).

WARNING: VOLTAGES IN EXCESS OF 300V DC ARE PRESENT WHEN THIS CIRCUIT IS POWERED.

CURRAWONG STEREO VALVE AMPLIFIER (AMPLIFIER SECTION)

Fig.1: the left channel circuit of the Currawong Stereo Valve Amplifier (the right channel is identical). The incoming signal passes through a low-pass RC filter and volume pot VR1 and is then fed into V1 (a 12AX7 twin triode) which provides signal preamplification in two stages. Its output is then fed to V2 (another 12AX7 twin triode) which operates as a phase splitter and gain stage to drive push-pull output pair V3 & V4 (both 6L6 or KT66 tetrodes). Output transformer T3 has tapped connections to the output valve screens for ultra-linear operation. The transformer output is switched to either the speaker terminals (via CON3) or to the headphone socket by relay RLY1.



SC 02014 CURRAWONG STEREO VALVE AMPLIFIER (POWER SUPPLY SECTION)

Fig.2: the secondaries of toroidal power transformers T1 and T2 are connected in series and rectified using a voltage doubler to produce a 310V HT rail. Most of the ripple is filtered out by a capacitance multiplier comprising high-voltage transistors Q1-Q3 and a 470nF polyester capacitor. T2's remaining 12VAC secondary drives the 6L6 filaments directly in a series/parallel configuration, while the 12AX7 filaments run from a regulated 12V rail produced by bridge rectifier BR1, a 2200µF filter capacitor and linear regulator REG1. IC1 provides an HT turn-on delay and soft start.

(ie, around 1µF) in series with a 9.1kΩ resistor. This sets the closed-loop gain of the preamp section at around 2.75, so that the following phase splitter receives around 3V RMS at maximum volume. Note, however, that there is also a feedback path from the amplifier's output, which we will cover later.

Phase splitter

The phase splitter is another 12AX7 twin triode, V2. The phase splitter provides some gain but its main job is to produce two similar drive signals with opposite phase for the grids of the push-pull output stage valves Signal is coupled to this phase splitter from V1b's anode via another 220nF polyester capacitor.

V2a operates as an inverter, to generate the out-of-phase drive signal. Like V1a and V1b, it is configured as a common-cathode amplifier. It runs from a higher HT rail of around 288V DC which comes from the first HT RC filter stage (6.8kΩ/39µF). Its grid is tied to ground by a 1MΩ resistor, with the voltage across the shared 6.8kΩ cathode resistor providing the required bias potential.

This resistor is shared with V2b (and both cathode currents flow through it). V2b's grid is connected straight to ground so when its cathode voltage increases, the grid-cathode bias voltage decreases. As such, when V2a's cathode current increases and its anode voltage drops, V2b's bias increases and thus V2b's anode/cathode current decreases, causing the voltage at its anode to rise.

So the signal at V2b's anode has the opposite phase to that at V2a's anode, ie, it is in phase with the signal from the preamp. The 220kΩ anode resistor value has been selected so that the two output signals have a similar swing and so that V2a and V2b both operate with as high an anode voltage as possible, to give maximum drive amplitude for the following stage.

These drive signals are applied to the grids of 6L6 output valves V3 & V4 via 220nF polyester capacitors. These grids are again tied to ground by 1MΩ resistors and there are 10kΩ series stopper resistors to prevent parasitic oscillation.

Output stage

V3 & V4 are self-biased using 330Ω 5W cathode resistors, with around 22V across each. This gives an operating current of about 65mA. Each output valve is powered from the main HT rail of around 308V, via the primary windings of T3, for a quiescent power of around 20W each.

Note that DC and AC currents flow in the two halves of the push-pull winding since both plates of the tetrodes are fed from the transformer centre-tap connection. However, the magnetic fields produced by these direct currents are cancelled, as they flow in opposite directions. This is important because otherwise the transformer would be magnetically saturated.

As the current split between V3 & V4 changes in response to the input signal however, an AC magnetic field is induced which is coupled into T3's secondary. The resultant voltage drives the speakers or headphones.

Since the output valve quiescent power of 20W is around twice the amplifier's power output of 10W per channel into 8Ω, this gives Class-A operation. With lower load impedances (for example, 4Ω), V3 or V4 may be fully cut off during signal peaks, giving Class-AB operation.

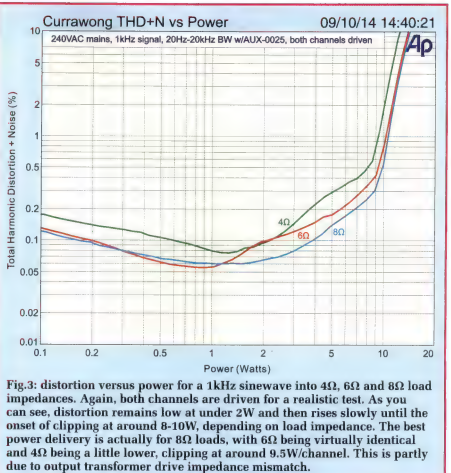


Fig.3: distortion versus power for a 1kHz sinewave into 4Ω, 6Ω and 8Ω load impedances. Again, both channels are driven for a realistic test. As you can see, distortion remains low at under 2W and then rises slowly until the onset of clipping at around 8-10W, depending on load impedance. The best power delivery is actually for 8Ω loads, with 6Ω being virtually identical and 4Ω being a little lower, clipping at around 9.5W/channel. This is partly due to output transformer drive impedance mismatch.

When the input signal swing is positive, pin 1 of V2a has a negative swing and so the current through V3 drops. At the same time, pin 6 of V2b has a positive swing and thus the current through V4 increases. This causes an increase in current flow from the top (dotted) side of T3's primary to the other, resulting in a positive swing at the dotted side of the secondary. Thus, the output of the amplifier is in phase with the input.

T3 also has taps approximately halfway between each end and the centre (HT) tap. These are connected to the screens of V3 & V4 via 47Ω stopper resistors, providing the ultra-linear connection mentioned earlier. This negative feedback from the transformer to V3 & V4 cancels out some of the transformer distortion. Note that while the feedback signals are high amplitude, the screen gain is much less than for signals applied to the grid, so the feedback doesn't overpower the drive signals.

Because the signal levels in the output stage are much higher and since 6L6 valves require much more filament

Parts List

Chassis/power supply

1 timber plinth with base (details to come)
1 top cover cut from 3mm clear acrylic (details to come)
1 small tube acrylic glue
1 front panel, code 01111142, 249 x 30mm
1 rear panel, code 01111143, 248 x 53mm
1 160VA 37+37+15+15V toroidal transformer (Altronics MC5337)
1 80VA 12+12V toroidal transformer (Altronics M5112)
4 screw-on 30mm equipment feet (Jaycar HP0830, Altronics H0890)
4 M4 x 15mm machine screws and nuts (for feet)
1 15mm anodised aluminium knob to suit VR1
1 snap-in fused IEC mains male socket for 1.6mm panels (Altronics P8325)
2 M205 250VAC 1A slow-blow fuses (one spare)
1 red chassis-mount RCA/RCA socket
1 white chassis-mount RCA/RCA socket
2 red RCA line plugs
2 white RCA line plugs
2 red binding posts (Jaycar PT0453, Altronics P9252)
2 black binding posts (Jaycar PT0461, Altronics P9254)
1 SPST ultra-mini rocker switch, 250VAC rated (Altronics S3202, Jaycar SK0975)
1 1m length 2-core mains flex
1 1m length 3-core mains flex
1 200mm length 3mm diameter black heatshrink tubing
1 200mm length 8mm diameter black heatshrink tubing
1 200mm length 20mm diameter black heatshrink tubing
1 1m length heavy duty red hook-up wire
1 1m length heavy duty black hook-up wire
1 1m length single-core shielded cable
1 1m length medium duty black hook-up wire
1 12-way screw terminal strip (Jaycar HM3194, Altronics P2135A)
6 M3 x 25mm Nylon screws and nuts
1 M4 x 6mm machine screw
2 M4 nuts
2 4mm ID shakeproof washers
1 4mm ID eyelet crimp connector
3 red 6.4mm crimp spade connectors
12 4G x 9mm self-tapping screws
10 small Nylon cable ties

Main board

1 double-sided PCB, code 01111141, 272 x 255mm
2 15W 100V line transformers (T1,T2) (Altronics M1115 – do not substitute)
2 5VDC coil 3A contact SPDT micro relays (RLY1,RLY2) (Altronics S4141B)
6 M205 fuse clips (F1-F3)
1 1A M205 slow-blow fuse (F1)
1 3A M205 slow-blow fuse (F2)
1 6A M205 slow-blow fuse (F3)
1 white vertical RCA socket (Altronics P0131) (CON1)
1 red vertical RCA socket (Altronics P0132) (CON2)
2 2-way vertical pluggable terminal blocks (CON3,CON4) (Jaycar HM3112+HM3122, Altronics P2512+P2532)
1 PCB-mount switched 6.35mm stereo jack socket with long pins (CON5) (Jaycar PS0190)
1 3-way vertical pluggable terminal block (CON7) (Jaycar HM3113+HM3123, Altronics P2513+P2533)
1 5-way vertical pluggable terminal block (CON8) (Altronics P2515+P2535)
4 chassis-mount phenolic 9-pin valve sockets with bracket (V1,V2,V5,V6) (Jaycar PS2082)
4 chassis-mount ceramic 8-pin valve sockets with bracket (V3,V4,V7,V8) (Altronics P8501)
6 2-way pin headers, 2.54mm pitch (LK1-LK6)
2 shorting blocks (LK4-LK5)
1 5-50kΩ 16mm dual gang log pot* (VR1)
2 6073B-type mini flag heatsinks
4 M4 x 10mm machine screws
4 M4 shakeproof washers
4 M4 nuts
8 M3 x 15-16mm machine screws
10 M3 x 10mm machine screws
12 M3 shakeproof washers
12 M3 nuts

current than 12AX7s, we run the filaments of V3 & V4 (and V7/V8) from 6.1V AC, slightly shy of the nominal 6.3V, due to compromises made in power transformer selection. It still works fine; it just takes a little longer for the valves to reach full emission after switch-on.

Speaker connections & feedback

A 470Ω 1W resistor across T3's secondary ensures that there is some load even if there is no speaker connected. This is necessary because operating a push-pull transformer-coupled amplifier with no load can lead to very high AC voltages at the valve plates and subsequent flash-over in the valve sockets.

T3's secondary connects to the speaker terminals via the normally closed contacts of RLY1 and pluggable terminal block CON3.

RLY1 is energised if headphones are plugged into the front panel socket, disconnecting the speaker and redirecting the signal to headphone socket CON5 via a 220Ω resistor.

If LK4 is fitted (and we recommend that it is), feedback is applied from T3's secondary to V1a's cathode via a 470nF capacitor and 22kΩ resistor. Since the output is in phase with the input, by applying some of the output signal to V1a's cathode, we effectively reduce the drive for V1a, giving about 14dB of negative feedback.

There is a limit to how much feedback can be applied in this manner due to the phase shift created by the inductance of T3. We have set the feedback to give as much distortion cancellation as possible, while keeping it stable with capacitive loads.

The circuit as presented is stable with several microfarads across the load, even when driving it with a square wave.

By the way, the 470nF capacitor in the feedback path is important as it damps shifts in valve bias in response to changes in mains voltages and valve temperatures.

With feedback enabled, input sensitivity is around 1V RMS. Typical CD/DVD/Blu-ray players produce around 2V RMS so this should be plenty in most circumstances. With LK4 re-

14 M3 Nylon nuts
22 3mm inner diameter Nylon flat washers
8 6.3mm M3 Nylon tapped spacers
2 TO-220 insulating washers and bushes
1 1m length medium duty blue hookup wire (250VAC rated)
1 1m length shielded audio cable
1 200mm length 3mm diameter blue heatshrink tubing
6 small green Nylon cable ties (maximum 2mm wide)
2 small blue Nylon cable ties
* *≥ 20kΩ recommended; substitute motorised pot for remote control option (see details in part two next month)*

Valves

4 12AX7 dual triodes (V1,V2, V5, V6)
4 6L6 beam tetrodes – matched pairs if possible (V3,V4, V7,V8)

Semiconductors

1 4093B quad NAND Schmitt trigger IC (IC1)
1 LM/LT1084-ADJ 5A adjustable low-dropout regulator (REG1)
1 KSC5603D 800V 3A high-gain NPN transistor (Q1)
3 STX0560 600V 1A NPN high-gain transistors (Q2-Q4)
3 BC547 100mA NPN transistors (Q5,Q7,Q9)
2 BC557 100mA PNP transistors (Q6,Q8)
1 red/green 2-lead bi-colour 3mm LED with diffused lens (LED1)
5 blue diffused lens 3mm LEDs (LED2-LED6)
1 W04 1.5A bridge rectifier (BR1)
2 1N5408 3A 1000V diodes (D1,D2)
3 1N4007 1A 1000V diodes (D4-D6)

Capacitors

1 2200µF 25V electrolytic
2 470µF 400V snap-in electrolytic
4 100µF 50V electrolytic
2 100µF 16V electrolytic
5 39µF 400V low-profile snap-in electrolytic (Nichicon LGJ2G390MELZ15) (Mouser)
2 1.5µF 63V MKT
5 470nF 630V polyester
2 470nF 63V MKT
8 220µF 630V polyester
1 100nF 63V MKT or 50V multi-layer ceramic
2 100pF ceramic disc

Resistors (1W, 5%)

9 1MΩ	2 9.1kΩ
2 270kΩ	4 6.8kΩ
2 220kΩ	2 3.3kΩ
2 120kΩ	2 680Ω
2 100kΩ	2 470Ω
6 47kΩ	2 220Ω
2 22kΩ	1 82Ω
5 10kΩ	4 47Ω
4 330Ω (5W, 10%)	

Resistors (0.25W, 1%)

7 1MΩ	1 560Ω
1 150kΩ	2 470Ω
2 10kΩ	1 330Ω
2 1kΩ	4 120Ω

moved, the overall gain is much higher and the input sensitivity is around 350mV RMS for full power. However, distortion rises to around 0.5% at 1kHz and >1% at lower frequencies.

Note that the 470nF series capacitors in the feedback network are important. These form high-pass filters in combination with the feedback resistors, with a -3dB point of around 15Hz. If DC feedback is used, the bias time constants in the circuit form a type of relaxation oscillator and the bias voltages never quite settle down, leading to asymmetric clipping and other undesirable behaviour.

Power supply

The separate power supply circuit is shown in Fig.2. All components, except the two power transformers T1 & T2, power switch S1 and the fused IEC mains socket, are on the main board.

There are three main power requirements for this circuit: the 310V HT rail, the ~12V DC filament supply for the 12AX7s (at around 1A) and ~6VAC for the 6L6 filaments, at around 4A. We also use the 12V DC rail to power various ancillary circuits, as described below.

All of T1's secondaries are connected in series, along with one of T2's secondaries, to produce 114VAC. T2's other secondary provides a little over 12VAC, to run the 6L6 filaments at around 6.1VAC each, in series pairs. The 12VAC is also rectified, filtered

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Most of the parts except mainly the power transformers are mounted on a single large PCB to make the assembly easy. The optional remote volume control is built on a separate PCB.

and regulated to provide the 12V DC rail (actually about 12.3V DC), for the 12AX7 filaments and DC-powered circuitry.

The 114VAC from CON7 is rectified in a half-wave voltage doubler consisting of 1000V 3A diodes D1 & D2 and two 470µF 400V capacitors, giving about 310V across both capacitors with several volts of ripple. Fuse F1 provides some protection against faults.

There are two 47kΩ series-connected bleeder resistors to discharge the 470µF capacitors when power is removed. Four blue LEDs are connected in series with the two 47kΩ 1W resistors. The blue LEDs indicate the presence of HT and also illuminate output transformers T3 and T4 (very effective in a room with subdued lighting).

The output stage has no HT low-pass filter, unlike the preamplifier and phase splitters. So to prevent HT ripple in the output stage from affecting the signal, we are using an active ripple filter. This is a capacitance multiplier filter built around high-voltage, high-current transistor Q1, configured as an emitter-follower.

The traditional HT filter is a large iron-cored choke but these are heavy and expensive, not to mention hard to find these days. Our transistor-based method is more effective and cheaper.

Q1 is driven by Q2 and Q3 which are high-voltage high-gain signal transistors, in a "Triplington" configuration; it's like a Darlington but with an extra stage. The higher the gain in this buffer, the more effective the filter is. Base bias comes from an RC low-pass filter across the incoming HT rail, consisting of a 1MΩ resistor and 470nF polyester capacitor.

Q2 and Q3 have a gain of around 70-100 each while Q1 has a gain of around 30. So the overall gain is about 70 x 70 x 30 = 147,000 which multiplies the effect of the 470nF capacitor to act as if it is 69,000µF! In practice, it isn't quite as good as this as the 470nF capacitor discharges slightly through the three base-emitter junctions at the trough of each ripple cycle but despite this, the ripple at Q1's emitter is just a few hundred millivolts.

Q1 has an integral emitter-collector diode so that when the unit is switched off, the output filter capacitors can safely discharge back into the input filter capacitors without doing any damage. D4 protects Q2 while D5 provides similar protection for Q3 but also has a role in the start-up delay, which we'll explain later.

Note that this arrangement also results in HT "soft-start" as it takes a few hundred milliseconds for the 470nF capacitor to charge and the HT rail tracks this voltage.

Turn-on delay

We have also incorporated a 20-second (or so) turn-on delay, to allow the valve filaments to heat up before HT

is applied. Part of the rationale for this is to prevent "cathode stripping" which can occur with cold cathodes, although the existence of this phenomenon is somewhat controversial. But since the valves aren't "ready" to operate immediately anyway, it certainly doesn't hurt to delay the application of HT.

IC1 is a quad Schmitt-input NAND gate which runs from the 12V rail and provides the turn-on delay. Note that ground for the 12V rail is labelled V_{EE} and will be close to, but not necessarily at, GND (0V).

IC1a is connected as an inverter with a 100µF capacitor from its input to ground. A 150kΩ resistor charges this capacitor from the 12V rail while a 1MΩ capacitor discharges it when power is switched off. It takes about 20 seconds for this capacitor to charge to a sufficient voltage for the output of IC1a to go low.

During this time, IC1a's output is high. This is inverted by IC1c and then again by IC1d, so Q4 (another 600V transistor) is switched on initially. This keeps the 470nF capacitor in the HT filter from charging until the delay has ended. Diode D5 in the HT filter prevents the base of Q3 from being pulled below GND when V_{EE} is (slightly) negative.

IC1a and IC1c also drive LED1 via two pairs of complementary emitter-followers (Q5-Q8). LED1 is a bi-colour device and consists of a red LED and green LED on the same die, connected in inverse parallel. Since inverter IC1c is between them, one inverter is always driving one end of LED1 high and the other is driving it low. Thus LED1 is red initially at turn-on and switches to green once the time-out period has expired and the HT rail is powered up.

A 1kΩ resistor sets the LED current to about 10mA while another 1kΩ resistor partially isolates the bases of Q5 & Q6 from IC1a's output. This allows the optional remote control board to independently drive LED1, in order to flash it to acknowledge infrared command reception. The remote control board connects via CON10 and will be described next month.

Low-voltage supplies

5-pin pluggable terminal block CON8 provides separate low-voltage AC connections for the 6L6 filaments (pins 1 & 3) and the regulated supply (pins 4 & 5). Each is fused on the board.

The PCB is slid into a slot that runs around the top inside edge of the timber plinth. Perspex covers will be used to protect the PCB and speaker transformers.

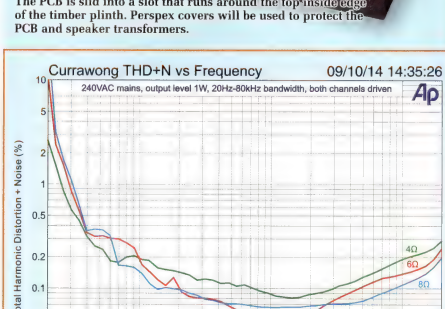

Fig.4: distortion versus frequency, with both channels driven at 1W into three different resistive loads. As you can see, the distortion is pretty low for a valve amplifier, especially between 100Hz and 10kHz. Below 100Hz, distortion rises steeply due primarily to the output transformer's non-linear response. Distortion into lower impedances is only slightly worse than that for 8Ω. Note the 80kHz bandwidth used, to ensure that higher frequency harmonics are included in the measurements.

However, we ultimately decided to use one transformer winding to power both, hence they are wired in parallel despite the separate connections.

The 12VAC from pins 4 & 5 of CON8 is rectified by 1.5A bridge rectifier BR1 and filtered with a 2200µF capacitor to produce around 15-16V DC with

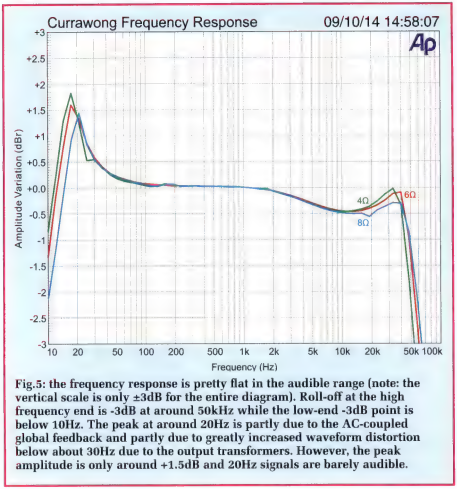

Fig.5: the frequency response is pretty flat in the audible range (note: the vertical scale is only ±3dB for the entire diagram). Roll-off at the high frequency end is -3dB at around 50kHz while the low-end -3dB point is below 10Hz. The peak at around 20Hz is partly due to the AC-coupled global feedback and partly due to greatly increased waveform distortion below about 30Hz due to the output transformers. However, the peak amplitude is only around +1.5dB and 20Hz signals are barely audible.

about 1V ripple. This is regulated to provide a nice smooth rail by REG1, a low-dropout, high-current equivalent to the LM317.

Pins 1 & 3 of CON8 connect straight to the series/parallel-connected 6L6 filaments and as a result, they get about 6.1VAC each. One end of this AC supply is grounded for noise immunity.

Now because of this ground connection and the fact that the same transformer secondary is used to feed BR1, the negative end of BR1 actually floats between about +0.7V and -15V. Hence, the need to disconnect V_{EE} from GND. If two separate 12V transformers or windings were used, LK6 could be fitted and thus V_{EE} would be at the same potential as GND. **LK6 must not be fitted with the supply arrangement shown here!**

The circuit will work the same regardless as to whether V_{EE} is connected to GND, as Q4 is the only connection between the two supply "domains".

The DC supply is also used to power relays RLY1 and RLY2 when headphones are plugged in. These are 5V relays, so an 82Ω series resistor drops the 12V DC to an appropriate voltage. LED2 is also connected across the relay coils, in series with a 330Ω current-limiting resistor, to indicate when the speakers are disconnected.

Unused linking options

Note that the supply was also designed to operate with the regulated rail at 6V DC rather than 12V. This would require a different transformer (ie, 6VAC rather than 12VAC) and the option was provided as there are some 12AX7-compatible valves with 6.3V-only filaments (rather than the typical arrangement with a 12.6V centre-tapped filament).

However, given the relative rarity of these valves, we aren't going to go into details as to how to reconfigure the supply except to say that LK1-LK3 are fitted for this purpose. Normally, they are left out.

PCB layout

We wanted to put as many parts on the PCB as possible to make this amplifier easy to build. Soldering parts to a PCB is certainly a lot easier than point-to-point wiring! It minimises the chances of mistakes and also means that performance will be consistent between amplifiers.

Warning!

Note: parts of this circuit operate at over 300V DC. Do not touch any components or any part of the PCB while the unit is operating or immediately after switch off. The blue LEDs in the circuit indicate when dangerous voltages are present.

The PCB layout was a bit tricky though, due to the voltages involved. We have kept tracks with voltages that may differ by over 60V apart by 2.54mm to prevent arcing, while in other areas low-voltage tracks need to be closer together so they can fit. We also used "star" earthing as much as possible to avoid hum and ripple injection into the preamp stages. Most of the grounds on the board converge on the main power supply filter capacitor negative pin.

The board has been designed with plated slots for the valve socket pins so that they fit snugly and neatly.

All connectors have been placed along the back of the board, on the underside, to keep the chassis wiring neat. The input signals run from the back of the board to the front (where the volume pot is mounted) through shielded cables that are strapped to the underside of the board, to prevent the low-level input signals from picking up ripple, hum and buzz.

We have also used low-profile components where possible, so that a clear perspex shield can be fitted over the top, to prevent prying fingers from getting a shock, as mentioned earlier. The valves, main filter capacitors and output transformers will pass through cut-outs in this shield, with perspex boxes around the transformers. The rest of the components will be safely underneath.

Next month

That's all we have room for this month. Over the next couple of months we will present the main PCB layout diagram, describe the assembly procedure, explain how to build the plinth and finish the wiring. We'll also go through the testing and troubleshooting procedure and describe the optional infrared remote control which uses a motorised potentiometer. SC

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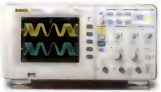

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By JOHN CLARKE

48V Dual Phantom Power Supply for DI boxes & Condenser Microphones

Lots of audio equipment needs phantom power. As well as condenser mikes, it's also required for active DI boxes, preamplifiers and effects units. This phantom power supply runs from a 24VAC plugpack transformer and delivers a regulated 48V DC via XLR sockets.

PUBLIC ADDRESS systems in theatres, churches and halls all require microphones, preamplifiers and possibly powered DI (direct injection) boxes and effects pedals for musicians. Many microphones are dynamic types that do not require a power source but the more sensitive condenser microphones require power and the same goes for other items of equipment.

While these can often be run from batteries, it is far more convenient to have a "phantom supply". This avoids the need to check batteries that can go flat at the most inconvenient times, ie, when you need 'em!

So what's a phantom supply? Well, it's a way of providing power to equipment via balanced signal leads. "Phantom" refers to the apparently invisible manner in which power is applied. 48V DC is the favoured phantom supply standard in the commercial sound industry. 24V and 12V are also used but these are not popular.

Fig.1 shows how it's done. The 48V DC supply is applied via 6.8kΩ resistors to the hot (non-inverted) and cold (inverted) signal leads for the device being powered. The output signal leads from the unit are capacitively coupled to the following device, so that the DC voltage is removed from the signal.

Phantom supplies should not be confused with the bias voltage applied to electret microphones. A bias supply is applied to an unbalanced lead comprising a shield and signal wire, rather than to a balanced signal line with a shield. Additionally, such a bias supply is typically around 1.5V and has a current of 1mA or less. More information about this can be found at: http://blog.shure.com/shure-notes/shure-tech-tip-phantom-power-vs-bias-voltage/

So what happens if a phantom supply is connected to a dynamic microphone? Will it be damaged by current flow? The answer is "no".

Fig.2A shows this connection. A dynamic microphone employs a coil

that's floating and not connected to the grounded shield. With 48V applied to both sides of the coil, no DC current flows through it.

Problems can arise when a dynamic microphone or the connecting lead is wired incorrectly, with one side of the microphone coil connected to ground as shown in Fig.2B. Current would then flow in the coil, leading to magnetisation that may permanently affect the microphone.

Problems also occur if a centre-tapped microphone coil is incorrectly connected to ground at the centre tap (Fig.2C). In this case, a different current may flow in each half of the coil due to slight differences in the values of the 6.8kΩ resistors and imbalances in the coil windings.

Getting back to Fig.2A, matching the 6.8kΩ resistors will also improve noise rejection due to more equal impedance matching in the two signal leads. For those unfamiliar with balanced audio leads, the twisted pair wires in the balanced lead carry out-of-phase signals. At the receiving end, the out-of-phase signals are "subtracted" and this has the effect of "adding" the two signals.

In addition, because they are twisted, the signal wires each tend to pick up the same level of hum and this is cancelled by the subtraction at the receiving end. A shield wire that's connected to ground further minimises hum and noise pick-up.

Some mixing desks do include a phantom supply for microphones, etc. However, even if you do have such a mixing desk, it may not have sufficient capacity. This new 48V Dual Phantom Power Supply can be used with two phantom-powered devices.

As shown in the photos, the 48V Dual Phantom Power Supply is housed in a diecast box, for ruggedness and for shielding. It has two female XLR sockets and two male XLR sockets. The 48V supply is applied to the female XLR sockets, while the male sockets provide the signal output with the DC voltage blocked by 22μF electrolytic capacitors.

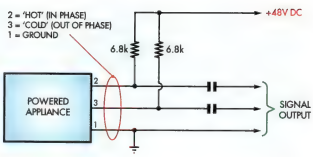


Fig.1: how phantom power is applied. The 48V DC supply is applied via 6.8kΩ resistors to the balanced signal leads of the device being powered.

Circuit details

Now take a look at Fig.3 for the full circuit details. As shown, the incoming 24VAC from the plugpack transformer is connected to a half-wave voltage doubler rectifier comprising diodes D1 & D2 and two 470μF 63V electrolytic capacitors. This will result in a nominal DC voltage of about 67V but will typically be much higher at around 75V DC, depending on the incoming mains voltage and the plugpack's voltage regulation.

REG1, an LM317 3-terminal adjustable regulator, is used to derive the 48V DC supply. This device is rated for a maximum differential of 40V between its input and output. With a 75V input and a 48V output, the input to output difference is a comfortable 27V but when power is initially applied, the regulator circuit's input can be 75V or more while the output can be as low as 1.3V. This is due to REG1's adjust terminal being initially held at 0V via a 1μF bypass capacitor.

Since the LM317 cannot cope with this admittedly brief overload, a pre-regulator comprising Darlington transistor Q1 and 33V zener diode ZD1 is used to protect it from over-voltage. Q1 acts as an emitter follower, while ZD1 has its anode connected to REG1's output, thereby limiting the voltage across the regulator to about 31.7V (after allowing for the voltage drop across the two base-emitter junctions in Darlington transistor Q1).

Following the pre-regulator, the circuit involving REG1 is fairly standard. REG1's supply input is decoupled using a 100nF MKT capacitor, while the output and adjust terminals are bypassed using 1μF 63V electrolytic capacitors.

The minimum load current for REG1 to give its specified performance is 12mA. Since the voltage between the output and adjust terminals could be as low as 1.2V, we would normally connect a 100Ω resistor between these two terminals to provide this minimum current. However, this wouldn't allow us to use convenient standard resistor values for the adjust-to-ground resistors and so we have used a 150Ω resistor instead. This provides a minimum load of 8mA, with the remaining 4mA required being added by the current through power indicator LED1.

In fact, assuming a 48V output and 2V across LED1, the LED current will actually be 4.6mA.

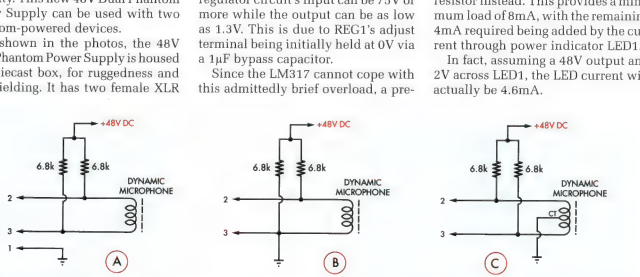
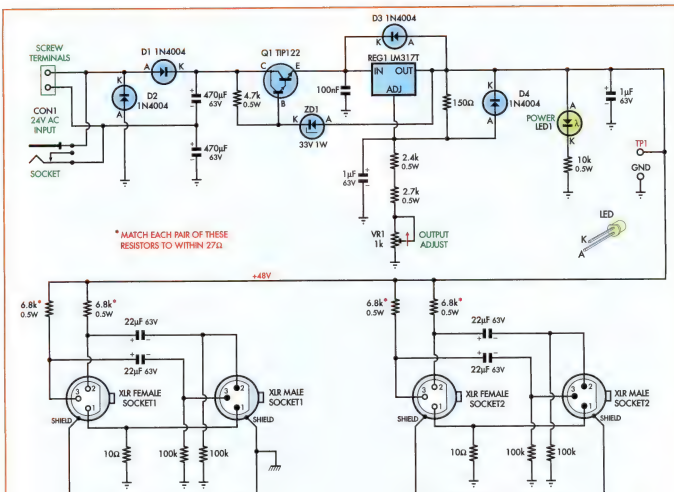


Fig.2: a correctly wired dynamic microphone coil is shown at (A) but problems occur if the microphone is incorrectly wired as shown at (B) and (C) due to current flowing in the coil.



SC 2014 48V DUAL PHANTOM POWER SUPPLY

Fig.3: the circuit of the 48V Dual Phantom Power Supply. The 24VAC supply input is rectified by voltage doubler D1 & D2 and fed to an LM317T adjustable regulator (REG1) via a pre-regulator consisting of Darlington transistor Q1 & ZD1. The resulting 48V DC output from REG1 is then fed to pins 2 & 3 of the female XLR sockets via 6.8kΩ resistors.

Trimpot VR1 (1kΩ) allows the output voltage to be adjusted from 40.8V to 48.8V if the output-to-adjust terminal voltage is at its 1.2V minimum. If the output-to-adjust terminal voltage is at its 1.3V maximum, the current through the adjust resistors is 8.66mA and the output voltage can be adjusted using VR1 from 44.2V to 52.8V.

These calculations do not include the current flowing from the adjust terminal itself. This is typically 45µA but can be as high as 100µA. For the adjust terminal to ground resistance used, this can add an extra 0.61V to the output.

Note that the output voltage is required to be between 44-52V in order for the phantom supply to comply with the DIN EN 61938 standard.

Diodes D3 & D4 are included as standard protection. D3 allows current flow from the output back to the input if the regulator's input is shorted. Similarly, D4 allows current to flow from the 1µF bypass capacitor at the adjust terminal if the output is shorted.

XLR sockets

The 48V DC supply is fed to the XLR sockets via 6.8kΩ resistors. These limit the short-circuit current to a nominal 7mA (6.5-7.7mA range) for each supply pin (pins 2 & 3 on the XLR sockets).

Ideally, each 6.8kΩ resistor pair should be matched to within 27Ω to comply with the 0.4% tolerance allowed by the phantom power specifications. That can be easily achieved by using resistors that are from the same manufacturer's batch.

In practice, the resistor values are checked with a digital multimeter before installation. The resistors in each pair do not need to be within 27Ω of 6.8kΩ; just within 27Ω of each other.

As mentioned previously, 22µF electrolytic capacitors are used to block the 48V DC on the balanced signal lines from being fed to the XLR male output sockets and these work in company with 100kΩ bias resistors from the outputs to ground. The 22µF capacitors ensure a low-frequency roll-off that's well below 20Hz for a typical sound mixer or amplifier input impedance of 10kΩ. The 10Ω resistors isolate the ground connections between each pair of female and male XLR sockets to prevent high-level ground loop currents.

By contrast, the shield connections of each XLR socket pair are connected together (but not to each other). In other words, the Female Socket1 shield connects to the Male Socket1 shield and the Female Socket2 shield connects to Male Socket2 shield. There is no interconnection between the two sets of shields.

In practice, the Socket1 pair shield is also connected to the metal case used to house the circuit. This connection is made via one of the mounting screws that's used to secure the XLR female socket to the case.

Construction

The 48V Dual Phantom Supply is built on a double-sided plated-through PCB coded 18112141 and measuring 56.5 x 113mm. This is housed in a diecast box measuring 122 x 66.5 x 39mm and a panel label (113 x 56mm) is affixed to the lid.

Fig.4 shows the parts layout on the PCB. Begin by installing the resistors, zener diode ZD1 and diodes D1-D4. A digital multimeter should be used to check the resistor values before they are installed. As mentioned above, you will need to select two pairs of 6.8kΩ resistors that are within 27Ω of each other.

Make sure the diodes are all installed with the correct polarity. The banded end of each diode must be orientated as shown on the layout diagram.

The PC stakes for TP1 and GND can go in next, followed by REG1 and Q1 (don't get these latter two parts mixed up). As shown, REG1 & Q1 are mounted horizontally, with their leads bent down by 90° so that they go through their respective PCB holes. Be sure to secure the metal tab of each device to the PCB using an M3 x 6mm machine screw and nut before soldering their leads.

Trimpot VR1 can now be installed, followed by the capacitors. Make sure the electrolytics are installed with the correct polarity.

The 2-way screw terminal block (CON1) is next on the list (wire entry holes towards the adjacent edge of the PCB). Alternatively, a DC socket can be fitted instead. A screw terminal block would normally be used, since AC plugpacks are usually supplied with bare leads.

Next, install the XLR sockets, making sure that they all sit flush against the PCB before soldering their leads. LED1 can then go in; it must be fitted with the correct polarity and with the top of its lens 30mm above the PCB so that it later just protrudes through the

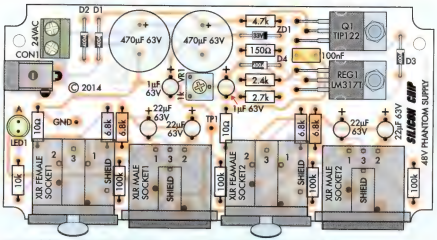
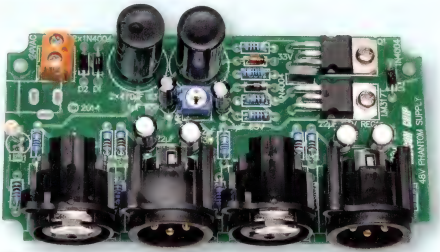


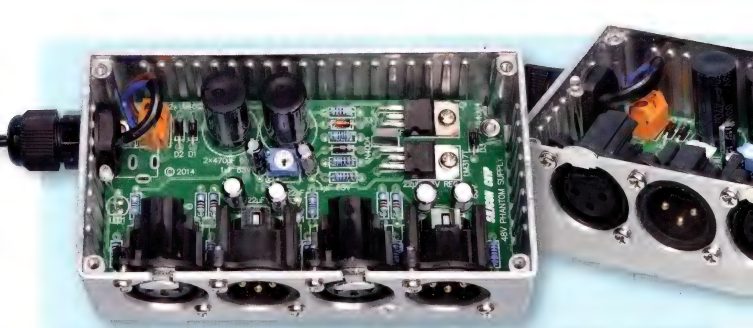
Fig.4: follow this diagram to install the parts on the PCB. LED1 should be mounted with the top of its lens 30mm above the board so that it will later protrude through the lid of the case.



This view shows the completed PCB assembly. Note that The top of each 470µF capacitor must be covered with insulating tape (12mm-diameter) to ensure that they cannot later short to the case lid.

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	4	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	4	6.8kΩ	blue grey red brown	blue grey black brown brown
❑	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	1	2.7kΩ	red violet red brown	red violet black brown brown
❑	1	2.4kΩ	red yellow red brown	red yellow black brown brown
❑	1	150Ω	brown green brown brown	brown green black black brown
❑	2	10Ω	brown black black brown	brown black black gold brown



The PCB is installed in the case by mounting it on two M3 x 6mm tapped spacers (secured with M3 x 12mm countersink screws) at the rear and by fitting six M3 x 12mm screws (one Nylon, the rest metal) into the XLR sockets at the front.

lid of the case. Note that the longer lead is the anode.

The PCB assembly can now be completed by covering the top of each 470nF capacitor with a circular piece of insulating tape cut to a diameter of 12mm. This is necessary to ensure that the capacitors cannot later short to the lid of the case.

Test & adjustment

Before going any further, check that all components are orientated correctly and that you haven't missed any solder joints. That done, apply 24VAC power and check that LED1 lights.

If it does, connect your multimeter between TP1 and GND and adjust trimpot VR1 for a reading of 48V. Check that 48V is also present at pins 2 & 3 of the XLR female sockets; ie, by measuring between each pin and GND.

Now check pins 2 & 3 of the XLR male sockets. They should each be at a low voltage and this should continue dropping over time as the 22µF capacitors fully charge. In fact, they may take several minutes to drop below 50mV, due to capacitor leakage current. If the voltage on one or more pins remains higher than 100mV, change the relevant capacitor. You can use low-leakage 50V capacitors if necessary.

Preparing the box

Before installing the PCB in the case, it's necessary to drill mounting holes for the XLR sockets and the two rear PCB mounting points. A hole is also required is the lefhand side of the case to accept a cable gland (for the 48VAC supply leads) or a DC plug, while a 3mm hole must be drilled in the lid for the power indicator LED.

Fig.5 shows the drilling template for the XLR sockets, while Fig.6 (the front panel artwork) shows the location of the LED (these can also be downloaded in PDF format from the SILICON CHIP website).

As shown, the XLR sockets require 22mm-diameter clearance holes, with 3mm-diameter holes for the mounting screws. The 22mm holes can be easily cut using an Irwin Speedbor or similar drill. These are intended for use in timber but they also work well on aluminium.

Drill just down to a depth where the internal ribs of the box begin; any further and the drill will begin to wobble. The inside piece can then be forced sideways in several directions by inserting a screwdriver in the centre hole and applying leverage. Do this until the inside piece eventually gives way and falls out, then clean up the hole with a round file.

If you don't have a Speedbor drill, drill a series of small holes around the inside perimeter of the hole, then knock out the centre piece and file the job to a smooth finish.

Each XLR female socket also requires a cut-out between the top of its 22mm hole and the top edge of the box (see Fig.5). This cut-out is necessary to allow the 'push to release' lever on each XLR female socket to be inserted. It's just a matter of making these cut-outs using a hacksaw after the 22mm holes have been drilled.

The two mounting holes for the rear of the PCB are marked out after the XLR cut-outs have been made. It's just a matter of temporarily fitting the PCB assembly into the case, marking out the two holes, the removing the PCB and drilling them to 3mm. Deburr the holes using an oversize drill, then countersink them from the outside to suit countersink-head M3 screws.

Next, drill the hole in the side of the case for the power cable (either to accept a cable gland or a DC power plug). This hole should be positioned

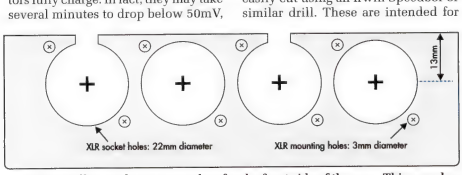


Fig.5: the drilling and cutout template for the front side of the case. This can also be downloaded in PDF format from the SILICON CHIP website.

towards the rear of the case must be directly in-line with the DC socket (if used).

Final assembly

Once all the holes have been drilled, the PCB assembly can be mounted in the case. The first step is to install two M3 x 6mm tapped spacers to support the rear edge of the PCB. Secure these using M3 x 12mm countersink head screws inserted up through the base of the case, then drop the PCB into position and fit nuts to hold the assembly in place.

The PCB assembly is secured to the front of case by fitting M3 x 12mm mounting screws to the XLR sockets. **Seven of these screws are metal but a Nylon screw must be used for the lower (righthand) mounting hole of XLR female socket2 (see photos).** This is necessary to prevent the screw from making a connection between this socket's shield and the case, thereby creating an earth loop (and causing hum). That's because the lower mounting hole of each female socket connects the shield to the case when a metal screw is used.

By the way, you will have to cut a thread in the plastic of XLR female socket2 with one of the M3 metal screws before replacing this with the Nylon screw. Do all the screws up so that there is a gap of about 2.5-3mm between the socket and the case, so that the lip on the inside of the lid will fit between them.

Front panel label

The front-panel label can be produced by printing it onto photo paper. This is then affixed to the case lid using a suitable glue or neutral-cure silicone and the hole cut out for the LED.

For a more rugged label, print a mirror image onto clear overhead projector film, so the print side will be on the back of the film when the label is affixed to the lid (eg, using silicone sealant). Alternatively, you can print onto an A4 sized synthetic 'Datafilex' self-adhesive label if you have an inkjet printer or onto a 'Datapol' self-adhesive label if you have a laser printer. Further information on where to buy these labels is in the panel in the Mains Switch Timer article published elsewhere in this issue.

Once the label is in place, it's then just a matter of attaching the lid using the four countersunk M3 screws provided and the 48V Dual Phantom Power Supply is ready for use. SC

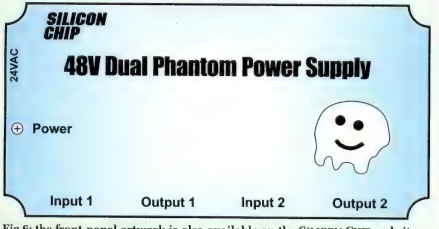


Fig.6: the front-panel artwork is also available on the SILICON CHIP website. You will need to drill a hole in the case lid for the power LED.

Parts List

1 PCB, code 18112141, 113 x 56.5mm
1 panel label, 113 x 56mm
1 diecast box 122 x 66.5 x 39mm (Altronics H 0453)
1 24VAC plugpack (50mA minimum rating)
2 XLR female 3-pin connectors (compact, PCB mount, 90°) (Altronics P 0875) (Female Socket1, Female Socket2)
2 XLR male 3-pin connectors (PCB-mount, 90°) (Altronics P 0874) (Male Socket1,Socket2)
1 2-way PCB-mount screw terminal block with 5.08mm spacings (CON1)
1 cable gland (3-6.5mm dia. cable)
1 PCB-mount DC socket, 2.1mm or 2.5mm (Jaycar PS-0520, Altronics P0620, P0621A – optional)
2 M3 x 6mm spacers
2 M3 x 10mm machine screws (to secure REG1 and Q1)
7 M3 x 12mm machine screws (for XLR socket mounting)
1 M3 x 12mm Nylon or polycarbonate screw (lower right female XLR socket mounting)
2 M3 x 12mm countersink-head screws (rear PCB mounting)
4 M3 nuts
2 PC stakes
1 25mm length of insulation tape
1 1kΩ mini horizontal trimpot (VR1)

Semiconductors

1 LM317T adjustable regulator (REG1)
1 TIP122 NPN Darlington transistor (Q1)
4 1N4004 1A diodes (D1-D4)
1 33V 1W zener diode (ZD1)
1 green 5mm LED (LED1)

Capacitors

2 470µF 63V PC electrolytic (26.5mm height maximum)
4 22µF 63V PC electrolytic
2 1µF 63V PC electrolytic
1 100nF MKT polyester

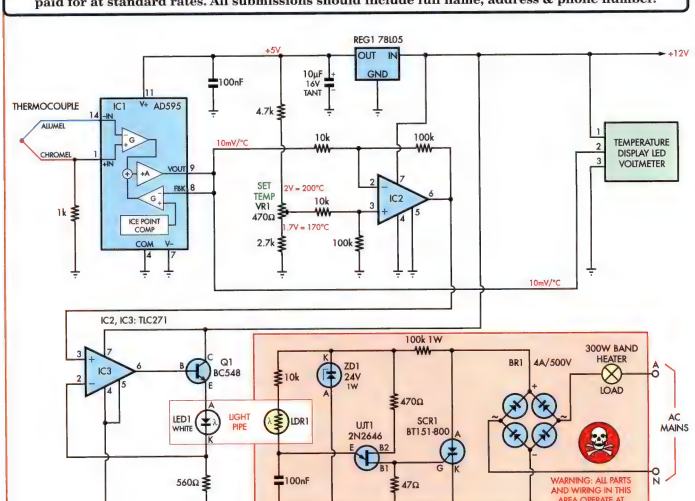
Resistors (0.25W, 1%)

4 100kΩ	1 2.7kΩ 0.5W
1 10kΩ 0.5W	1 2.4kΩ 0.5W
4 6.8kΩ 0.5W*	1 150Ω
1 4.7kΩ 0.5W	2 10Ω

* Select each pair to be within 27Ω of each other

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.



Thermocouple-based thermostat with temperature display & proportional phase control

A cheap thermocouple, a compensation IC, LED voltmeter and a few other parts can be used to build a very useful thermostat which controls a mains-powered heater proportionally over a wide temperature range. Most of these parts are available on eBay.

With a 5V DC supply, an Alumel/Chromel (Type K) thermocouple can be used to sense temperatures over the range of 0-300°C. An AD595 (IC1) provides cold junction compensation so that the output is relative to absolute temperature, not ambient temperature. Its output is fed to a LED voltmeter which originally displayed a range of 0-99.9V but was modified to turn off the decimal point and change the resolution to 10mV.

This was done by bypassing the input resistor of its onboard potential divider (labelled R15, 1104 = 1.1MΩ) and connecting the incoming wire directly to its onboard calibration trimpot. This pot was then readjusted so that when fed a 3V signal, the display read 30.0. Pin 3 of the LED display was then cut to disable all the decimal points. The voltmeter was purchased on eBay: www.ebay.com.au/itm/DC-Digital-Display-Voltmeter-Voltage-Green-LED-Panel-Meter-0-99V-3-Wire-CarGauge-/350817907651

To provide the thermostat function, the target temperature is adjusted using VR1. The difference between the voltage at its wiper and the

20-LED moving dot temperature display

This circuit provides a 20-segment temperature display, indicating from 0-30°C in 1.5°C steps. It also has an under-temperature LED which turns on when the temperature is below 1.3°C and an over-temperature LED for when it's above 31°C.

The temperature is measured using an LM35 precision temperature sensor, IC2, which provides a linear DC output voltage that's proportional to the temperature in °C. Its output is connected to two cascaded LM3914 dot/bar drivers, IC3 & IC4, to provide a 20-segment display (in dot mode). A separate LM393 dual comparator provides the under and over-temperature indication.

Each LM3914 contains 10 individual comparators referenced to a precision ladder divider. Both ends of the divider are available at pins 4 & 6 so the upper and lower reference voltages can be set.

The LM35's output voltage is nominally 10mV/°C but in this circuit, negative feedback has been applied which increases that to 100mV/°C so that for example at 25°C, the output is 2.5V. A resistive divider is placed between the OUT terminal and ground, with the GND terminal of IC2 connected to the mid-point. The upper part of the divider is a fixed 200Ω while the lower part is adjustable between 1kΩ and 3kΩ using VR2.

Ignoring IC2's operating current, when the divider ratio is 10:1, ie, 1.8kΩ in the lower "leg", the voltage at the OUT terminal is multiplied by a factor of 10. That's because for every volt the OUT terminal increases, the GND terminal increases by 0.9V, so with the differential voltage between OUT and GND at 100mV (for 10°C), the voltage between GND and the circuit ground will be 900mV.

IC2's operating current increases

continued on page 48

measured temperature is multiplied by a factor of 10 by IC2, a TLC271 low-drift rail-to-rail op amp. IC2 is configured as a differential amplifier. The lower the measured temperature is compared to the set temperature, the higher IC2's output voltage.

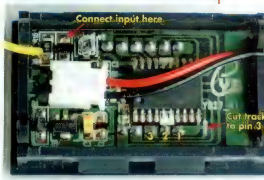
IC3, another TLC271, operates as a voltage-to-current converter. It maintains the voltage across the 560Ω resistor to match the pin 6 output of IC2, so with IC2's output at 1V (ie, monitored temperature 10°C below the set-point), there will be 1V across the 560Ω resistor, meaning that LED1 is driven at 1V ÷ 560Ω = 1.8mA. The harder LED1 is driven, the lower LDR1's resistance will be.

LED1's output is coupled to LDR1 using a light-pipe which can be a TOSLINK cable, length of clear PVC or an acrylic rod (with suitable light shielding, eg, opaque heatshrink).

As LDR1's resistance drops, the time constant of the low-pass filter comprising the LDR itself, the 10kΩ resistor and the 100nF capacitor decreases. As a result, SCR1 is turned on sooner during each mains half-cycle, once the 100nF capacitor charges to a high enough voltage to cause unijunction transistor UJT1 to conduct. When it does, the capacitor charge is dumped into SCR1's gate and the rectified 230VAC is connected across the heater.

So, as the sensed temperature drops (or the set temperature increases), the heater is turned on for more of the time, bringing the temperature back up. Similarly, if the sensed temperature is too hot, power to the heater is reduced. This method of control gives tighter temperature control than the more typical hysteretic (on/off) control.

The 4.7kΩ and 2.7kΩ resistors either side of VR1 give a range of 1.7-2V at VR1's wiper, allowing the target temperature to be set in the range of 170-200°C. For a different range, change these fixed resistor values,



This photo shows how the LED voltmeter is modified.

or use a higher value pot for a wider spread of minimum and maximum temperatures. The minimum practical setting is around 70°C while the upper limit is about 300°C as set by the wattage of heater used and the 5V supply.

Finally, note that the circuitry in the red shaded area operates at mains potential (ie, 230VAC).

John Russull,
Tottenham, UK. ($50)

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Moving dot temperature display – ctd from page 47

the voltage across the lower divider leg but this small current of around 50µA is swamped by the 200µA/°C across the 200Ω resistor.

The output of IC2 is fed to the IN terminals (pin 5) of IC3 & IC4 and also to pins 2 & 5 of IC1. With pin 4 (Rlo) of IC3 at 0V and pin 6 (Rhi) at 1.5V, the internal window comparators have thresholds of 0.15V, 0.3V, 0.45V, etc, corresponding to 1.5°C, 3.0°C, 4.5°C and so on. So LED2 at output O1 (pin 1) turns on when the temperature is below 1.5°C, O2 for 1.5-3.0°C and so on, ending with O10 which turns on when the temperature is between 13.5°C and 15°C. Above 15°C, IC4 takes over as its Rlo input is at 1.5V and Rhi is at 3.0V.

The upper voltage tap on this resistor ladder is set to 3.0V by adjusting VR4 which forms part of a voltage divider between the Vref pin (pin 7) and REFadj pin (pin 8) of IC3. REFadj is maintained at 1.25V so a reference voltage of 3.0V is achieved with VR4 set to around 400Ω, forming a 1kΩ:1.4kΩ divider.

In this case, the voltage at the REFadj pin is 3.0V x 1kΩ ÷ (1kΩ + 1.4kΩ) = 1.25V. The current pulled from the REFadj pin also sets the output LED current. In this case, it is 1.25V ÷ 1.4kΩ x 10 = 9mA each.

For under-range LED1, IC1a pulls its cathode low when its pin 2 inverting input, driven by IC2, is below the reference voltage on its pin 3 non-inverting input which is set to 0.13V by adjusting VR1. IC1b works in the opposite manner, with its output going low when the voltage from IC2 is above 3.1V, driving LED22. When LED22 is on, drive for LED21 is cut off since D1 is forward biased, so only one of LED21 and LED22 is on at a time.

Note that while set in "dot" mode, the small amount of noise on the signal can cause two adjacent LEDs to be partially switched on simultaneously. If you would prefer "bar" mode, where multiple LEDs are lit (ie, the same LED that would be lit in dot mode plus all the lower-numbered ones down to LED2), connect each pin 9 of IC3 and IC4 to the 9V supply rail.

Mahmood Alimohammadi, Tehran, Iran. ($50)

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Efergy Elite Power Monitor MS-6200
The large, easy to read LCD display gives you clear live power consumption, live running costs, stores your usage by day/week/month, and calculates your average daily, weekly and monthly power and running costs. Add the MS-6205 Engage Online Monitoring Hub (sold separately) to start monitoring your home energy usage online and in real-time using the free Smartphone/Tablet App available for both Android and iOS.

Efergy E2 Classic Power Monitor MS-6202
In addition to the functions offered by MS-6200, the MS-6202 features a USB port to download the data into the Efergy software supplied for further analysis. Includes USB cable.

FROM $99

Efergy Engage Home Hub Kit MS-6204
The ultimate solution for the most tech savvy users, allowing you to monitor your power usage in real time from anywhere via Smartphone/Tablet/PC using free app (available for Android and iOS) and internet connection. The Engage Hub connects to your internet router, which then uploads the data to Efergy's cloud server for further analysis. Includes Engage Hub, mains power supply and Ethernet cable. Capable of monitoring up to 8 transmitters (extra transmitters MS-6203 sold separately). Note: Indoor LCD display not included.

Efergy Elite Power Monitor	MS-6200 $99
Efergy E2 Classic Power Monitor	MS-6202 $129
Efergy Engage Home Hub Kit	MS-6204 $129

Accessories available:
2 x Sensors to Suit MS-6200/2/4 (for 3-Phase Systems)
MS-6201 $39.95
Efergy Engage Hub to Suit MS-6202
MS-6205 $89.95

MS-6200

NEW

NEW SCIENCE KIT!

Potato Clock

You can generate enough electricity to run a digital clock by plugging electrodes into common potatoes! An amazing chemical experiment which also works with tomatoes, lemons, apples - even soft drink or beer! All parts (except fruit/veg) supplied including:

$9.95

- Highly accurate digital clock module
- Metal electrodes and wire
- Instructions and fluid beakers
- Perfectly safe for children and highly educational (Fruit/veg not to be consumed after use)
- Clock size: 65(W) x 30(H) x 12(D)mm
- Recommended for ages: 10+

KJ-8937

WE HAVE MOVED

Hobart
Lot 1, 187/205
Main Rd, Moonah
TAS 7009

Visit our NEW premises

Ph: (03) 6272 9955

LED Light Globes

A range of dimmable mains LED light globes that is a true replacement for traditional lighting, offering brilliant lumen performance with wide and evenly spread light.

- Natural white, 4000K colour temp
- Available in bayonet or screw cap

FROM $12.95

NEW LOWER PRICE

VINBRIGHT
The bright side of light

5W	450 Lumens Bayonet	SL-2212	WAS $14.95 NOW $12.95 SAVE $2
5W	450 Lumens Screw	SL-2213	WAS $14.95 NOW $12.95 SAVE $2
8W	650 Lumens Bayonet	SL-2232	WAS $22.95 NOW $14.95 SAVE $8
8W	650 Lumens Screw	SL-2233	WAS $22.95 NOW $14.95 SAVE $8
10W	900 Lumens Bayonet	SL-2216	WAS $29.95 NOW $19.95 SAVE $10
10W	900 Lumens Screw	SL-2217	WAS $29.95 NOW $19.95 SAVE $10

Also available in warm and cool white.

SL-2232

LED Magnifying Lamp

Magnify and illuminate objects. Great tools for technicians, researchers or for general hobby work that involves soldering, connecting wires between small parts, and other fiddly jobs.

- 127mm lens diameter
- 5 dioptre lens
- Mains powered

QM-3548

$99 NEW

Suitable Rolling Floor Base
QM-3549 $89.00

Jaycar Electronics
Better. More Technical

DOUBLE REWARDS POINTS!

Cat II Autoranging DMM

Quality DMM with 15mm high digits and backlit LCD for easy reference.

$19.95 DOUBLE POINTS

- Cat II 600V, 2000 count
- AC/DC voltages up to 600V
- AC/DC current up to 10A
- Resistance measurement, autoranging, data hold
- Size: 140(H) x 70(W) x 31(H)mm

QM-1524

Cat III True RMS DMM

A powerful true RMS multimeter that includes non-contact voltage testing, backlit LCD, and a carrying pouch.

$59.95 DOUBLE POINTS

- Cat III 600V, 4000 count
- AC/DC voltages up to 600V
- AC/DC current up to 10A
- Temperature, resistance, capacitance, frequency and more
- True RMS for accurate readings
- Autoranging, continuity, diode check
- Size: 138(L) x 68(W) x 37(D)mm

QM-1551

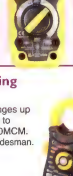
Cat IV Heavy Duty True RMS DMM

Rugged and waterproof (IP67), designed to withstand harsh environments for electrical, industrial and other professional uses. Drop proof up to 2 metres.

$109 DOUBLE POINTS

- Cat IV 600V, 4000 count
- AC/DC voltages up to 1000V
- AC/DC current up to 10A
- Resistance, frequency, continuity, diode, temperature and more
- True RMS for accurate readings
- Size: 180(L) x 82(W) x 57(D)mm

QM-1574



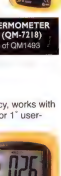
CAT III Insulation Tester/Multimeter

Suitable for high voltage insulation testing up to 4 gigaohms at up to 1000V. It also has AC/DC voltage and low resistance multimeter functions.

$199

- Cat III 1000V, 4000 count
- Test Voltage & Current: 125V, 250V, 500V, 1000V @1mA nominal
- Insulation resistance up to 4000M Ohm
- Dual analogue/digital backlit display
- Bargraph, test hold & lock functions
- Size: 200(L) x 92(W) x 50(D)mm

QM-1493



FREE*! NON-CONTACT THERMOMETER VALUED AT $29.95 (QM-7218)
* Valid with purchase of QM1493

Cat IV True RMS DMM with Smartphone App

View live measurements, trend graphs, data log, and email your results or upload them to the Cloud - all from your Smartphone!

- CAT IV 600V, 40000 count
- AC/DC voltages up to 1000V
- AC/DC current up to 10A
- Bluetooth® and PC connectivity
- Data hold/storage, triple LCD display
- Size: 182(L) x 82(W) x 55(D)mm

QM-1576 WAS $219.00

$189 SAVE $30

CAT III 400A Autoranging AC/DC Clampmeter

Quality clampmeter with current ranges up to 400A AC/DC and 30mm jaw size to accommodate conductors up to 350MCM. Perfect for the working installer or tradesman.

- Cat III 600V, 4000 count
- AC/DC voltages up to 600V
- AC/DC current up to 400A
- Resistance, capacitance, frequency, temperature and more
- Data hold, non-contact voltage, relative measurement
- Size: 198(H) x 66(W) x 36(D)mm

QM-1563

$119

Non-Contact Thermometer with Dual Laser Targeting

$99

Measure the temperature of any surface from a safe distance with this compact sized non-contact thermometer. With a wide temperature range and laser targeting, this portable instrument is easy to use for quick and accurate temperature checking of any surface.

- Temp range: -50°C to +650°C (±1%)
- Size: 146(L) x 104(W) x 43(D)mm

QM-7221

Temp/Humidity USB Datalogger

Log temperature and humidity readings and store them in internal memory for later download to a PC. Mounting bracket and software included.

- Windows 2000/XP/Vista compatible
- Temp range: -40 to 70°C (±1°C)
- Humidity range: 0 to 100% (±3°C)
- 32,000 memory samples

$119

QP-6013

Also available:
USB/LCD Model QP-6014 $149.00 (Shown)

2-Input Thermocouple Thermometer

Fast response and laboratory accuracy, works with K-type thermocouples and offers 0.1 or 1° user-selectable resolution over the entire measurement range. Holster and thermocouples included.

$79.95

- 2000 count
- Auto power off
- Range: -50 to 1300°C (±0.5%)
- Celsius & Fahrenheit measurements
- Backlit LCD, max and hold functions
- Size: 172(H) x 84(W) x 42(D)mm

QM-1601

FREE*! K-TYPE PROBE VALUED AT $14.95 (QM-1282)
* Valid with purchase of QM1601

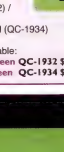
Compact Digital Sound Level Meter

Measure sound levels between 30 to 130dB and can be set for fast or slow responses. Data hold, min/max functions. Backlit LCD. Supplied with carry case, wind sock and battery.

$99

- 3.5 digit display
- A and C selectable weighting
- Size: 210(L) x 55(W) x 32(D)mm

QM-1589



Professional Laser Distance Meter with Smartphone App

Measure distance, area, and volume. Store the last 20 measurements for easy comparison and referral. Pair with a Smartphone to email measurements with a picture or upload to the Cloud.

- Range: 0.05 to 70m (±1.5mm)
- Requires 2 x AA batteries
- Size: 134(L) x 52(W) x 30(H)mm

QM-1624

$209

Free Digitech LDM app available from the App Store℠ and Google Play™

Digital Light Meter

A handy light meter for photography, lab work, architectural, engineering and construction. 4 ranges from 0.01 to 50,000 Lux. Battery and case included.

- 3.5 digit readout
- Auto zeroing, data hold
- Separate Photo Detector

QM-1587

$49.95

Digital Storage Oscilloscopes

Ideal DSO for the advanced hobby user or technician. Full data storage capabilities and USB interface. Portable, easy to use.

FROM $499

- Sampling rate: 500MSa/s (QC-1932) / 1GSa/s (QC-1934)
- Memory depth: 32k (QC-1932) / 2M (QC-1934)

Basic and professional models available:
25MHz Dual Channel with 5.7" Screen QC-1932 $499.00
100MHz Dual Channel with 7" Screen QC-1934 $899.00

FREE*! 100:1 OSCILLOSCOPE PROBE KIT VALUED AT $59.95 (QC-1903)
* Valid with purchase of QC-1932 or QC-1934

To order call 1800 022 888 **www.jaycar.com.au**

Savings off original RRP. Limited stock on sale items

TOOLS BONANZA

1000V 6-Piece Electronic Screwdriver Set

Set of six slotted and phillips screwdrivers with ergonomic and insulated handles. Excellent non-slip grips. Storage case included.

TD-2026

See website for full contents.

FREE*! KEYRING SCREWDRIVER VALUED AT $2.50 (TD-2086)
* Valid with purchase of TD-2026

$19.95

1000V 7-Piece Screwdriver Set

High quality, bright red drivers that are insulated right to the tip. Storage case included.

TD-2022

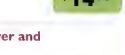
See website for full contents.

$24.95

Nibbling Tool

Will cut any shape out of aluminium, plastic, copper and other unhardened metals up to 18 gauge. Designed to fit in the palm of your hand for easy use, simply drill a 1/4" hole to start.

TH-1768



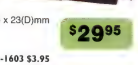
$14.95

3-in-1 Heat Blower and Soldering Iron

A handy unit with flame/flameless heat blower and soldering iron function. Great for general heating, drying, melting, soldering, heat shrinking, etc.

- Piezo ignition
- Child resistant latch
- Up to 500˚C
- Size: 148(L) x 35(W) x 23(D)mm

TH-1604



$29.95

Also available:
1mm Conical Tip TH-1603 $3.95

Anti-Static Field Service Foldable Mat

Ideal for anyone who manufactures, repairs or services sensitive electronic equipment.

- 3mm thick, hard wearing face
- Includes a ground lead, wrist strap and 2 pouches
- Mat folds out to approx. 600 x 600mm

TH-1776

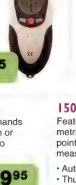
$49.95

3-in-1 Stud Detector with Laser Level

Indicates proximity when you are near a stud via its large LCD and shows a target graphic when you're spot on. Also has built-in laser level and voltage detection. Battery included.

- Continuous live wire detection
- Thumb dial adjustable feet for levelling the laser
- Size: 180(H) x 67(W) x 38(D)mm

QP-2288



$49.95

SOLDERING BUNDLE PACK

A must have for your workbench! This soldering package includes essential items you need to do an awesome soldering job. See website for full specifications.

Kit includes:

60W Lead-Free Digital Soldering Station	**TS-1390**	**$149**
Metal Desoldering Tool	**TH-1862**	**$16.95**
1mm Lead-Free Solder 200g	**NS-3094**	**$17.95**
Goot Soldering Iron Tip Cleaner	**TS-1510**	**$17.95**
PCB Holder with Movable Arm	**TH-1980**	**$19.95**

Total valued at over $220!

SOLDERING BUNDLE DEAL $169
DEAL INCLUDES TS-1390, TH-1862, NS-3094, TS-1510, & TH-1980
SAVE $52.80

Great Bundle Price

$169
SAVE OVER $50

ELECTRICAL SERVICE BUNDLE PACK

Useful service aids for electrical jobs. See website for full specifications.

Kit includes:

Isopropyl Alcohol 99.8% Spray	**250ml**	**NA-1066 $8.95**
Circuit Board Lacquer	**175g**	**NA-1002 $11.50**
Circuit Board Cleaner	**175g**	**NA-1008 $11.50**
J-B Weld Epoxy Pack	**25ml**	**NA-1518 $14.95**
Black Liquid Electrical Tape	**118ml**	**NM-2832 $24.95**

Total valued at over $70!

SERVICE AID BUNDLE DEAL $49.85
DEAL INCLUDES NA-1066, NA-1002, NA-1008, NA-1518 & NM-2832
SAVE $22

Great Bundle Under $50

$49.85
SAVE OVER $20

Digital Bench Scale

Precision 1kg electronic scale with 0.01g resolution. Weighs in grams, ounces, pounds, grains, carats and troy ounces.

- Automatic calibration
- Tare and counting function
- Powered by mains or batteries (not included)
- Size: 175(W) x 75(H) x 260(D)mm

QM-7264

$149

Inspection Camera with 3.5" Detachable Wireless LCD

View and record video and pictures in confined and dark locations. The head and flexible boom are IP67-rated for use in harsh environments.

- 1m flexible boom
- 2.4GHz wireless transmission
- Hook, mirror, magnet and 2GB microSD card included

QC-8712

$249

Also available:
Extension Shaft 2m QC-8702 $79.00

LED Headband Magnifier

This magnifying headset leaves both hands free and can be worn over prescription or safety glasses. Ideal for jewellery, radio electronics & camera repair, etc.

- Adjustable head strap
- Built-in LED work light
- 1.5X, 3X, 8.5X or 10X magnification
- Requires 2 x AAA batteries

QM-3511

$29.95

150mm Precision Digital Vernier Calipers

Features a 5 digit LCD display that will show readings in metric and imperial. The caliper can be zeroed at any point along the scale making comparative measurements easy. Battery included.

- Auto power off
- Thumbscrew slide damper
- Resolution: 0.01mm / 0.0005"

TD-2082

$29.95

Pocket Moisture Meter

An intelligent meter suitable for measuring water content in building materials and wooden fibre articles. Features 8mm electrode and backlit digital LCD screen. Carry case and batteries included.

- Range: 6 to 44% (wood) / 0.2 to 2.0% (material)
- Size: 96(H) x 40(W) x 20(D)mm
- Lightweight, only 83g

QP-2310

NEW

$29.95

"Condura" Style DC Rocker Switches

Superb looking rocker switches that you see in 70-100ft luxury motor cruisers. Basic switch comes with double-LED illumination, a standard rocker cover and a standard range of decals to customise the switch toyour application. For more professional finish, special laser-etched covers are available to match the basic switches.

- Rated 20A @12V, 10A @24V

Typical decals include: windscreen wipers, horn, heater & many more.

$12.95 ea NEW

BASIC SWITCHES

White	SK-0910 $12.95
Red	SK-0912 $12.95
Blue	SK-0914 $12.95
Amber	SK-0916 $12.95

LASER-ETCHED COVERS

12V Power	SK-0920 $2.95
Fridge	SK-0921 $2.95
Aux Battery	SK-0922 $2.95
Interior Light	SK-0923 $2.95
Spot Lights	SK-0924 $2.95
Horn	SK-0925 $2.95
Rear View Camera	SK-0926 $2.95
Inverter	SK-0927 $2.95
Driving Lights	SK-0928 $2.95
Thermofan	SK-0929 $2.95

DEAL! BUY SWITCH & COVER FOR $13.90 SAVE $2!
SWITCH INCLUDES ONE UNIT OF SK-0910, SK-0912, SK-0914 OR SK-0916 COVER INCLUDES ONE UNIT OF SK-0920, SK-0921, SK-0922, SK-0923, SK-0924, SK-0925, SK-0926, SK-0927, SK-0928 OR SK-0929

12/24VDC HIGH POWER LED LIGHT BARS

5,400 Lumen LED Light Bars

This high power single row LED light bar uses six 10W Cree® XM-L LEDs to produce a whopping 5,400 lumens - equivalent to a 400W halogen. Virtually unbreakable IP68 waterproof and aluminium construction, stainless steel mounting brackets. Shock and vibration resistant.

NEW

- Input voltage: 9-36VDC
- High quality PWM thermal management electronics
- Beam distance: 474m (SL-3970) / 316m (SL-3971)

$249 ea

Spot or flood beam available:
12" long, Spotlight SL-3970 $249
12" long, Floodlight SL-3971 $249

Spot/Flood Combo LED Light Bars

This high power dual row LED light bar features high quality Osram LEDs with extremely optically efficient lenses. Virtually unbreakable IP68 waterproof and aluminium construction, stainless steel mounting brackets. Shock and vibration resistant.

FROM **$499**

- Input voltage: 9-30VDC
- High quality PWM thermal management electronics
- Beam distance: 755m (SL-3982) / 1163m (SL-3984)

Available in 2 sizes:
20" Long, 8,400 Lumens SL-3982 $499
40" Long, 16,800 Lumens SL-3984 $899

NEW

500 Lumens Mini LED Driving Lights

Amazingly bright, an all-round solution for many different applications. Equivalent to a 35W halogen. Virtually unbreakable IP68 waterproof and aluminium construction, stainless steel mounting brackets. Shock and vibration resistant.

- 12/24VDC
- Input voltage: 9-60VDC
- Beam distance: 145m (SL-3916) / 50m (SL-3915)
- Compact 70(H) x 40(W) x 55(D)mm
- Sold individually

$49.95 ea

Spot or flood beam available:
Spotlight SL-3916 $49.95
Floodlight SL-3915 $49.95

DEAL! BUY 2 FOR $79 SAVE $20.90

3500 Lumens 5" LED Driving Lights

Extremely bright vehicle driving lights that only draws 34W of power. Equivalent to a 300W halogen. Virtually unbreakable IP68 waterproof and aluminium construction, stainless steel mounting brackets. Shock and vibration resistant.

$129 ea

- 12/24VDC
- Input voltage: 9-36VDC
- Beam distance: 378m (SL-3919) / 183m (SL-3918)
- Sold individually

Spot or flood beam available:
Spotlight SL-3919 $129
Floodlight SL-3918 $129

DEAL! BUY 2 FOR $198 SAVE $60

12VDC Mounting LED Headlamp Modules

Extremely bright drop-in replacement LED headlights for your car. Each kit contains 2 x 25W per LED bulbs, 2 x controller assemblies, and all the wiring is pre-terminated to appropriate connectors to make installation as quick and easy as possible.

$139 ea SAVE $30

- Cree® XLamp CXA1512 LED
- Ballast size: 65(L) x 50(W) x 16(H)mm

H4 (High / Low Beam) Cree® Module
- 1600/1800 Lumens per LED bulb

SL-3498 WAS $169 NOW $139 SAVE $30

H7 Cree® Module
- 1800 Lumens per LED bulb

SL-3499 WAS $169 NOW $139 SAVE $30

Warning: State road and traffic authorities do not allow retrofitting of these products to cars with ordinary headlights - even if it's really simple to do so.

Slim Ballast HID Light Kits

HID provides far greater light output than standard automotive lights. This series of kits all feature a slim ballast design for ease of installation in engine bays and tight spaces.

- 12V 6000K colour temp
- 300% more light than halogen

H1 Slim Ballast HID Kit	SL-3490 $49.95
H3 Slim Ballast HID Kit	SL-3492 $49.95
H4 Slim Ballast HID Kit	SL-3494 $49.95
H4 Slim Ballast HID High + Low Kit	SL-3495 $79.95
H7 Slim Ballast HID Kit	SL-3496 $49.95

Note: Please ensure your lights are angled correctly. These lights are not ADR approved.

FROM **$49.95**

12/24VDC CIGARETTE LIGHTER SOCKET SPLITTERS

Limited stock. Not available online.

UP TO 20% OFF

2-Way Splitter

- LED power indicator light

PP-2005 WAS $9.95

$7.95 SAVE $2

2-Way Splitter with 2 x USB Ports

- Plug can be rotated 180˚
- Power on/off switch function
- USB output: 5VDC 2A (max)

PP-2128 WAS $19.95

$16.95 SAVE $3

Limited stock

4-Way Splitter with 1 x USB Port

- Dash or console mounted
- Mounting hardware included
- USB output: 5VDC 1A (max)
- 1.2m long lead
- 10A max

PS-2019 WAS $19.95

$17.95 SAVE $2

Energy Saving Powerboard

Save power and money by automatically switching off appliances when not in use. 6 power sockets: 1 x control, 1 x always-on and 4 x auto-off sockets.

- 10A, 2400W rated
- Surge protection: 700 joules
- Size: 340(L) x 120(W) x 35(D)mm

MS-4081 WAS $39.95
NOW $29.95 SAVE $10

Also available: **Energy Saving Powerboard with IR Sensor for AV MS-4080 WAS $69.95**
NOW $49.95 SAVE $20 (shown)

FROM $29.95
SAVE UP TO $20

Travel Adaptors

These travel adaptors will allow you to use your AU/NZ appliances while travelling overseas.

$9.95 ea

Europe, Middle East, Asia
PP-4023 $9.95
UK, HK, Singapore, Malaysia
PP-4024 $9.95
USA, Japan, Thailand, Taiwan
PP-4025 $9.95

Note: These do not convert voltages.

Vertical Power Tower

A versatile 8-outlet power board with 2 x 1A built-in USB ports to charge any USB product. Surge and overload protected.

- 10A, 2400W rated
- Surge protection: 3150 joules
- Size: 225(H) x 170(W) x 170(D)mm

MS-4023 WAS $69.95

$54.95
SAVE $15

USB Mains Power Adaptor

Features worldwide voltage input, perfect mobile device charging solution for home and travel needs.

- Input voltage: 100-240VAC, 50/60Hz

FROM $24.95

2 Ports (2 x 2.1A)
MP-3459 $24.95

4 Ports (2 x 2.1A) + (2 x 1.0A)
MP-3454 $29.95 (Shown)

TRACK YOUR POWER & SAVE $$

Mains Power Meter

Shows how much an appliance is costing to run and tracks the total power being used. Shows instantaneous voltage or current being drawn and peak levels.

- 10A max rated

MS-6115

$19.95 ea

DEAL! BUY 2 FOR $29.95 SAVE $9.95

Portable 4000mAh Power Bank with Solar Charger

Charged via the included 12V in-car cigarette USB charger or from the built-in solar panel. It has two USB ports that output up to 2.1A. Supplied with 6 interchangeable connectors to suit many devices, and a carabineer so you can attach it to a bag.

- Size: 76(L) x 33(W) x 29(D)mm

MB-3615 WAS $69.95

$59.95
SAVE $10

Universal Battery Charger

Recharge Li-ion battery packs, AAA/AA and 9V Ni-MH and Ni-Cd rechargeable batteries

- Includes USB charging port (500mA)
- Size: 120(L) x 62(W) x 35(H)mm

MB-3639

Batteries not included

Rechargeable Ni-MH batteries:
AAA, Pack of 4 SB-1739 $10.95
AA, Pack of 4 SB-1738 $16.95

$39.95

DEAL!
CHARGER + BATTERY BUNDLE
DEAL 1
MB-3639 + SB-1739
FOR $40.90 SAVE $10
DEAL 2
MB-3639 + SB-1738
FOR $41.90 SAVE $15

0-260VAC Variable Laboratory Autotransformer (Variac)

Controls AC voltage and of voltage-dependent parameters such as current, power, temperature, light intensity, motor speed etc. It enables the AC input to a mains powered appliance to be easily varied from 0 to full line voltage (or greater). Encased in heavy-duty steel housing.

- Rated power handling: 500VA (fused)
- Input voltage: 240VAC @50Hz
- Output Voltage: 0–260VAC @50Hz
- Size: 165(D) x 120(W) x 160(H)mm

MP-3080 WAS $229

$189
SAVE $40

10% OFF STEPDOWN TRANSFORMERS

Non-Dielectrically Isolated Transformer

Includes overheat protection. Two-pin US 110 - 115V socket and cord plug for 240V power.

- 50W rated
- 240VAC to 115VAC

MF-1091 WAS $49.95

$44.95
SAVE $5

Dielectrically Isolated Transformers

Quality fully-enclosed stepdown transformer with fold up metal carry handles, approved 3-wire power cord & two-pin US 110 - 115V socket. Suitable for use with precision electric and electronic appliances.

- 240VAC to 115VAC isolated
- Includes a resettable circuit breaker

See website for specifications.

FROM $89
SAVE UP TO $37

MF-1086

120W	MF-1080 WAS $99	NOW $89	SAVE $10
250W	MF-1082 WAS $129	NOW $116	SAVE $13
500W	MF-1084 WAS $229	NOW $206	SAVE $23
1000W	MF-1086 WAS $369	NOW $332	SAVE $37

DC to DC Converter Modules

DC voltage converter modules that will output user selectable voltages (excluding AA-0238). These could be used to power 12VDC devices from a 6VDC motorbike battery or to run 12VDC devices from a 24VDC source such as those found in trucks.

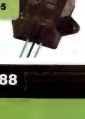
- Protection against short-circuits, overload and overheating
- Compact size and features mounting holes

1.5A AA-0236 $24.95
- 6-26VDC Input, 3-15VDC Output

2.0A AA-0237 $29.95
- 6-14VDC Input, 11-26VDC Output

1.1A AA-0238 $24.95
- 24VDC Input, 12VDC Output

FROM $24.95



TINNED COPPER SINGLE CORE CABLES

7.5A & 15A Tinned Cables

Flexible heavy duty tinned copper cables suitable for general purpose, automotive and marine applications. Supplied on easy to use 10m handy pack reel and available in 3 colours.

FROM $7.95

7.5A 18/19 AWG		15A 16 AWG	
Red	WH-3045 $7.95	Red	WH-3054 $12.95
Black	WH-3046 $7.95	Black	WH-3055 $12.95
Green	WH-3047 $7.95	Green	WH-3056 $12.95

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PARTY BONANZA

SAVE UP TO 30% ON THESE PARTY LIGHTS

This portable LED flashing strobe light, has a magnetic base which can be placed on any iron/steel surface.

- Powered by 3 x AAA batteries or 4.5V power supply (not included)

Available in 3 colours

Red	SL-3325 WAS $14.95	NOW $9.95	SAVE $5
Blue	SL-3327 WAS $14.95	NOW $9.95	SAVE $5
Amber	SL-3329 WAS $14.95	NOW $9.95	SAVE $5

$9.95
SAVE $5

Note: Limited stock. Not available online.

This 5-channel DMX Par 64 spotlight offers complete control over stage, party or DJ lighting setup. Designed for easy installation, safe, energy efficient and long life operation. Individually addressable via DIP switch and include a mounting bracket.

- Mains powered
- Channels: red, green, blue, brightness, strobe
- Size: 245(L) x 195(Dia)mm

SL-3424 WAS $99

$89
SAVE $10

This compact 14-channel DMX moving spotlight features a user selectable 540° pan and 270° tilt and 9 gobos plus open and wheel spin effect. Built-in movement macros via master/slave or DMX.

- Mains powered
- Variable electronic strobe/dimmer
- Size: 249(H) x 173(W) x 173(D)mm

SL-3440 WAS $299

$269
SAVE $30

Note: Limited stock. Not available online.

This compact 2-channel DMX Par 64 spotlight offers 3 operating modes: sound-active, automatic and DMX control. It features 177 UV emitting LEDs, brightness control, strobe effect and a built-in microphone.

- Mains powered
- Channels: brightness, strobe
- Size: 240(W) x 200(H) x 310(D)mm

SL-3466 WAS $119

$105
SAVE $14

NOTE: Snow machine liquid may cause eye or skin irritation and can be slightly slippery on smooth surfaces. Handling and safety directions available online.

SPECIAL DEALS FOR SPECIAL EFFECTS

Bubble Machine

Create instant, continuous bubbles with this affordable portable bubble machine!

- Mains or battery powered (2 x C batteries, sold separately)
- 280mm long

AB-1220
WAS $34.95

$24.95
SAVE $10

Spare Bubble Liquid 946ml AB-1222 $6.95

FREE*! BUBBLE LIQUID 946ML VALUED AT $6.95 (AB-1222) *Valid with purchase of AB-1220

Snow Machine

Produces a jet of small foam balls which float majestically to the ground like real snow. The resulting blanket of snow dissolves slowly leaving minimal residue.

- 240VAC operation
- Size: 337(L) x 210(W) x 170(H)mm

AF-1216 WAS $99

$79
SAVE $20

Spare Snow Juice 1L AF-1217 $9.95

FREE*! SNOW JUICE 1 LITRE VALUED AT $9.95 (AF-1217) *Valid with purchase of AF-1216

Fog Machine

Produces clouds of white fog on demand. Fantastic for use with laser light shows, mirror balls and other party lighting.

- Mains powered with 3m wired remote controller
- 800ml fog juice capacity
- Size: 330(L) x 160(W) x 140(H)mm

AF-1214 WAS $99.95

$89.95
SAVE $10

Spare Fog Juice 1L AF-1212 $17.95

FREE*! FOG JUICE 1 LITRE VALUED AT $17.95 (AF-1212) *Valid with purchase of AF-1214

SAVE OVER 10% ON DJ EQUIPMENT

XLR LED Light with Gooseneck

No DJ or engineer should be without one of these. Four bright LEDs provides enough light to see what you're doing without disturbing the audience.

- Powered by phantom power
- 400mm long

AM-4124
WAS $24.95

$21.95
SAVE $3

Note: Limited stock. Not available online. Mixing console not included.

Multifunction Megaphone

A battery operated megaphone with built-in message record feature for repeat announcement replay. Lightweight and portable with shoulder strap.

- Power output: 10WRMS
- Built-in alarm, whistle and LED torch
- Requires 8 x AA batteries (not included)
- Size: 270 (L) x 162(W) x 235(H)mm

AM-4055
WAS $69.95

$62.95
SAVE $7

DJ Mixer

Two channels each with RCA inputs for CD or other line level source and a set of dedicated phono inputs. The BPM counter is capable of accurately measuring the beats per minute automatically.

- Level meters on each channel
- 2 band EQ on each channel
- Phono and line level inputs
- Mic and headphone outputs
- Line level preamp outputs
- Selectable CF curve
- Size: 330(W) x 22(H) x 102(D)mm

AM-4206 **WAS $149**

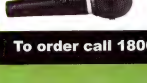
$129
SAVE $20

XLR Unidirectional Microphone

Dynamic, unidirectional microphone with an anti-pop grille, built-in on/off switch and XLR termination. Supplied with a 3m XLR to 6.5mm plug cable.

- Frequency response range: 50Hz to 13kHz
- Sensitivity: -50dB
- Output Impedance: 600 ohm

AM-4192



$14.95

Desktop Mic Stand

Excellent build quality with diecast aluminium legs, steel column and padded feet.

- Adjustable up to a height of 200mm and folds up to 240mm long
- Includes mic holder with 5/8" adapter

AM-4111

$17.95

USB MIDI Interface

Connect any MIDI device to your computer: keyboards, controllers, instruments, sound cards, samplers, drum machines etc.

- Plug and play, no software or drivers required
- MIDI in and MIDI out connectors
- 2m long cable

XC-4934 WAS $29.95

$19.95
SAVE $10

Limited Stock. Not Available Online

To order call 1800 022 888

www.jaycar.com.au

Savings off original RRP. Limited stock on sale items

SAVE UP TO 20% ON EDUCATIONAL KITS

Electric Current Experiment Kit

Learn the common principles of electric current and magnetism.

- Assembly time: 30min
- Requires 2 x D batteries, scissors, and tape (not included)
- Size: 99(L) x 70(W) x 45(H)mm
- Recommended for ages 8+

KJ-8901 WAS $9.95

$7.95

SAVE $2

Snap-on Electronic Project Kits

Simple snap together electronic project kits, no tools or soldering required. Both kits are great educational tools with fun bright coloured pieces. See website for full details of the projects. Recommended for ages 6+.

80 Experiments
KJ-8970 WAS $19.95 NOW $16.95 SAVE $3 (Shown)
50 Experiments
KJ-8972 WAS $24.95 NOW $20.95 SAVE $4

FROM **$16.95**

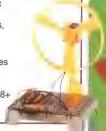
SAVE UP TO $4

12-In-1 Electrical Experiment Kit

Learn practical electronic principles such as static electricity, electric motors, solar power and more.

- Assembly time: 10min
- Requires 2 x AA batteries
- Base size: 120(L) x 99(W) x 23(H)mm
- Recommended for ages 8+

KJ-8919 WAS $24.95



$20.95

SAVE $4

PC Programmable Line Tracer Kit

Learn about robotics and programming. Run it in line tracer mode by drawing a thick dark line on paper for the robot to follow.

- Requires 2 x AA batteries
- Size: 120(L) x 64(W) x 55(H)mm
- Recommended for ages 12+

KJ-8906

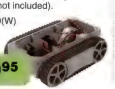
$29.95

Heavy Duty Robot Chassis

Virtually unbreakable glass reinforced ABS plastic vehicle chassis. Comes assembled with 2 x 6V motors with gear trains and includes gear grease and allen key (electronics not included).

- Overall size: 172(L) x 130(W) x 60(H)mm
- Recommended for ages 12+

KR-3130



$69.95

Asuro Programmable Robot Kit

Autonomous multi-sensor robot ideal for hobbyists and school projects. RISC processor robot "brain" featuring two odometers and several display elements.

- Some soldering required
- Recommended for ages 14+

KR-3120

$79.95

POPULAR ARDUINO COMPATIBLE PRODUCTS

Eleven

"Eleven" is based on the Arduino Uno but with improvements. Top spec ATmega328P Microcontroller, independent prototyping area, visible LEDs, and firmly mounted micro-USB connector to power your Eleven from most cellphone chargers! Includes USB cable and guide sheet.

XC-4210

$39.95

EtherTen

Talk to the world with all the features from Eleven and the Ethernet Shield combined in a single, integrated board. Includes onboard Ethernet, a USB-serial converter, a microSD card slot for storing gigabytes of web server content or data, and even Power-Over-Ethernet support.

- ATmega328P MCU running at 16MHz
- 10/100base-T Ethernet built-in

XC-4216

$69.95

StepDuino

A self-contained board with onboard stepper motor drivers, servo interface, microSD card slot, and 20x4 character LCD. Perfect for building robots or other mechatronics projects: just connect the stepper motors and go!

- 2 x 4-wire stepper motor controllers
- 1 x servo interface
- Serial communications header
- Compatible with the Arduino IDE
- Size: 113(W) x 74(H) x 25(D)mm

XC-4249

$149

128x128 Pixel OLED Display Module

High resolution, full colour 128x128 pixel OLED module perfect for your display needs including graphics, gauges, graphs and interactive displays.

- 16,384 full colour RGB pixels
- 28.8 x 26.8mm active display area
- Size: 44(W) x 36(H) x 5(D)mm

XC-4270

$49.95

DOUBLE POINTS

Large Dot Matrix Display Panel

This large, bright 512 LED matrix panel has onboard controller circuitry designed to make it easy to use straight from your board.

- 32 x 16 high brightness blue LEDs on a 10mm pitch
- Viewable over 12 metres away

$39.95

DOUBLE POINTS

Red LED Display **XC-4250 $39.95 (shown)**
Blue LED Display **XC-4251 $89.95**

3.2" LCD Touchscreen Display Kit

Add an interactive touchscreen display to your existing Arduino projects. Draw lines, shapes, text, display images, play sound and log data to microSD card. Includes LCD display, 4D Arduino Adaptor Shield, 5way interface cable and USB programming adaptor with pre-loaded software.

- Operating voltage: 4.5 ~ 5.5VDC
- Screen display area: 64.8 x 48.6mm
- Screen resolution: 240 x 320 pixels
- 65K True to life colours

XC-4280

$119

DOUBLE POINTS

Switchmode Power Regulator

This is a high tech switchmode supply with a selectable 5V or 7VDC output. The input voltage range of 6 to 28VDC is very flexible and it will not overheat at higher input voltages like the 7805 and other linear regulators may.

- Up to 1A output current
- Suits EtherTen or EtherMega POE

XC-4258

$19.95

3-Axis Accelerometer Module

This module can operate in either +/-1.5g or +/-6g ranges, giving your project the ability to tell which way is up. Perfect for Arduino projects, robotics projects, tilt sensors, vehicle dataloggers, and whatever else you can dream up.

- Independent X, Y, and Z axis outputs
- Can run from either 5V or 3.3V
- Zero-G free-fall detection

XC-4226

$19.95

IR Temperature Sensor Module

Connect this to your board and point it at a surface or heat source to remotely measure its temperature. Includes onboard power supply, communication support and a software library and examples.

- -33 to +220°C measurement range

XC-4260

$34.95

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SECURITY BONANZA

Outdoor Security Camera with PIR

Motion activated video recording in HD 720p to microSD card (32GB microSD card $47.95 XC-4982 sold separately). Features infrared LEDs for day/night use, LCD display, schedule function, and playback on PC/TV.

$159

- IR range up to 9m
- 5MP colour CMOS sensor
- Weatherproof IP66 camera
- Powered by batteries or 6VDC power supply (not included)
- Size: 140(H) x 75(Dia)mm

QC-8027

High Volume Wireless Doorbell

Rings with loud sound and strobe light. Ideal for use in a factory or for the hearing impaired.

$49.95

- Portable, up to 30m range
- 7 selectable melodies
- Requires 4 x C cells (not included)
- 210mm long

LA-5002

Motion Activated Tracking Spotlight

A unique way to protect your home against intruders. Motion is detected via the two front facing PIR sensors. Once activated, the light will pan left or right to follow a person. The 4 x 3W LEDs combine to produce a remarkable 500 lumens of light.

$119 DOUBLE POINTS

- Rotational range of light: 240°
- Detection up to 13m away depending on vertical angle
- PIR sensor and LED built into base
- Built-in dummy camera with blinking LED
- Size: 215(L) x 77(Dia)mm

SL-2705

2.4GHz Wireless DVR Kit with Solar Powered Camera

No wiring needed! This DVR kit has a solar powered digital wireless camera with PIR sensor and 2 x 5W LED lights.

$299

- Kit includes DVR receiver with mains adaptor, remote control, camera sensor light with rechargeable Li-ion battery, solar panel and USB and AV cables
- Solar charged camera
- Supports up to 4 cameras
- DVR size: 207(L) x 92(W) x 77(D)mm

DEAL! WIRELESS DVR BUNDLE DEAL - QC-3644 + QC-3646 FOR $389 SAVE $109

QC-3644

Spare camera QC-3646 $199.00

2.4GHz Digital Wireless Video Doorphone

Not your average video doorphone. This unit incorporates PIR motion detection on the camera face and will record any visitor within range. It will also take crystal clear images of your visitor pressing the doorbell.

NEW

$269

- 3.5" LCD wireless monitor
- Up to 80m range
- IP55 weatherproof camera
- Power supplies and mounting hardware included
- Camera size: 74(W) x 134(H) x 31(D)mm

QC-3400

Spare 3.5" LCD Wireless Monitor QC-3402 $159.00

Solar Rechargeable LED Floodlight

The 3W solar panel comes with a bracket allowing you to bolt it onto a surface to catch as much sunlight as possible. LED light automatically turns on when darkness falls, and activates when the PIR detects motion. 3m cable included.

$159 DOUBLE POINTS

- 10W cool white LED
- Light size: 175(H) x 145(W) x 53(D)mm

SL-2808

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Savings off Original RRP.

Prices valid from 24th October 2014 to 23rd November 2014.

Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock.

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Solar Smoothing:

what happens when the sun goes out?

While past Governments have been actively encouraging the installation of solar power systems (with generous buy-back schemes) on the rooftops of Australia, that's caused no end of headaches for power distributors.

by Ross Tester

The 50kVA 'Solar Smoother' recently installed by Magellan Power at the new Carnarvon (WA) Police and Justice Centre.

The electricity generating and distribution system has major difficulties in coping with the quality and quantity of power injected back into the grid from the huge numbers of private solar power generation systems. This has forced some electricity generators and distributors to impose limits on the amount of solar injection they will accept.

On a bright, sunny day when all of the photovoltaic systems are generating peak power, it amounts to an over-supply, because it's not possible to instantly adjust the system to cope.

And while feed-in systems theoretically provide "clean" power back to the grid, it's not always so.

Of course, the photovoltaic panels do not supply constant power – output rises gradually from zero around dawn to a peak at midday, falling once again to zero at night. While this can be taken into account by thermal or even hydro generators, it still requires careful management. Over-voltage, even by a relatively small amount, is responsible for significant equipment failure.

The opposite side of the equation is perhaps even more of a problem. If it's a cloudy day, or worse, a large cloud temporarily covers a town or suburb's solar panels, the solar power injection level will suddenly drop and generators will have to work doubly hard to maintain the power authority's guarantees of quality. Then the sun comes out again and . . .

The peaks and troughs need to be "filled in" to achieve a constant supply for industry, commerce and domestic customers.

In July 2012, the WA regional utility Horizon Power introduced a new specification called 'Generation Management for Solar Installers' to ensure a smoothing device was installed on every new solar power system to help with power fluctuations.

This provides backup power to the grid while the generators ramp up and down, reducing long term wear and tear of the equipment.

Another WA company, Perth-based Magellan Power, has recently delivered its first 'Solar Smoother' to the new $52.2 million Carnarvon Police and Justice Complex.

This does exactly what its name suggests – it smooths out the peaks and troughs of a typical solar panel installation.

It's no shrinking violet, either: the Magellan Solar Smoother supplied to the WA government is rated at 50kVA and occupies a cabinet some 2400 x 800 x 2000mm (other models are available in ratings from 5kVA to 100kVA). This contains modular MPPT battery chargers, 3-phase bidirectional IGBT-based inverters and lithium-iron-phosphate ($LiFePO_4$) batteries. Because it contains both chargers and inverters, there is no need for an external inverter.

Systems are available to suit PV installations of 200-470V DC, with a voltage window of 190-265VAC. Frequency window is 46.5Hz-53Hz, with energy efficiency between 90 and 95%. Single and 3-phase models are available and they will detect over-voltage, under-voltage, over-frequency, under-frequency and islanding (lack of grid supply). Similarly, battery over-temperature, under-voltage and over-voltage are all monitored. Transient response is just one second.

44 days of logged data are held in non-volatile memory (at 15 minute sampling intervals), or a year of data logged at two hour intervals. Data is accessible via RS232/RS485 and USB ports.

Magellan Power has more than twenty years experience in the power electronics industry, designing and manufacturing AC and DC power systems for both backup and grid-connect applications. The company also offers a range of other power control systems, for domestic and industrial applications.

Contact MagellanPower on (08) 9434 6621 or via their website, www.magellanpower.com.au

SERVICEMAN'S LOG

Heat can be a real killer in laptops

Dave Thompson*

The computer servicing business is changing and I'm now seeing increasing numbers of tablets and laptops, as opposed to the more-traditional desktop machines. A big problem with laptops is overheating due to dust build-up inside them and improper user attempts to remove this dust.

As I may have mentioned before, the computer servicing business is changing and events at my workshop over the past few months have illustrated just how much. Most readers will be aware that Microsoft has killed off support for its once favourite son (Windows XP) and is pushing people instead onto Windows 8. The result is a lot of confused and sometimes irate customers who end up buying an Apple Mac instead.

Aside from the natural reluctance we all have to change, you also have to factor in the collateral financial damage due to existing hardware not wanting to run later versions of Windows. In addition, other (often-expensive) software might not be compatible with later Windows versions and so upgrading suddenly takes a darker turn.

When clients ask me why they have to change, I give them the usual spiel about technology, progress, security and compatibility. However, with XP a familiar and still functional operating system and their hardware happy to keep on running it, it can be a tough sell to convince some to upgrade. For others, its all the motivation they need to defect to Apple.

The demise of XP isn't the only event making an impact on the computer repair landscape, though. When taken in context with the surge in popularity of the likes of smartphones and tablets, many customers are electing to not repair or upgrade their old desktop when it inevitably fails. Instead, they are choosing to use a laptop, smartphone or tablet to do the job, whether it is checking the latest racing results, bidding on an online auction, replying to emails or surfing the net.

You can perform all these tasks on an internet-connected smartphone or tablet, though admittedly some find it a bit fiddly until they get used to virtual keyboards and such. But when faced with a large bill to replace an old desktop machine, a lot of people are looking seriously at these alternatives.

In the past week alone, I've had three customers who decided to forgo repairing their broken desktop PCs. One guy had a laptop he'd purchased a while back but hadn't used much because he didn't like the fact that it had a smaller screen and keyboard than his desktop machine. However, he soon figured out that he could plug a keyboard, mouse and the otherwise redundant desktop monitor into it, to create a very usable substitute when his desktop PC failed.

The other two customers went down what is becoming a well-worn path among my clients. At some stage in the past, they had both either purchased or been given iPads or iPhones and like many people, had been seduced by their form and function. When I gave them the bad news that their respective Windows-based desktop machines had failed and needed replacing, they both went out and bought an iMac instead, their reasons being that they liked the way iOS worked, the devices all "talked" to each other and it just made sense to keep things the same across devices.

In real terms, this all means that I'm now getting more tech-support calls for laptops and tablets (and, to a lesser extent, smart-phones) than desktops. All of these devices have their own unique problems and while it seems an obvious step to just recalibrate

Items Covered This Month

- Heat is a killer for laptops
- Sony KDL52Z5500 TV set
- Zapped QED A270 amplifier
- Remote spotlight repair

*Dave Thompson runs PC Anytime in Christchurch, NZ.
Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

the business to include the repair of these devices, this isn't as easy or as practical as it first appears. That's mainly because most of these gadgets are now so cheap to buy that they are not economical to repair, even if you can find the parts for them.

When people hear how much it is likely to cost to fix their tablet or smartphone, most elect to junk it and buy another one. In fact, I would say that as many as eight out of 10 of my customers choose not to proceed with such repairs. This leaves me in the unenviable position of either (1) charging an assessment fee, which will likely result in the person getting miffed and not returning (because, in their eyes, I've made them pay for doing nothing), or (2) not charging for the assessment work, leaving me working for nothing and quietly going broke.

Sticking my neck out

I'll go on record and state that tablets will soon have had their day and that the sale and use of desktop and laptop computers will rise again, though likely not to the same levels they were before. This is because users will discover that while tablets are very handy for taking on holiday or checking the odd racing result or composing the odd email, you can't easily write a 500-word report on one, let alone an article for a magazine or something like a novel. Their fiddly virtual keyboards and small screens simply make those jobs too difficult.

I know I'm sticking my neck out but I think that once the novelty wears off, normal service will likely resume. Fortunately, laptops are a different animal from smartphones and tablets and servicing and repairing them may well keep companies like mine alive.

There are a host of things that can go wrong with a laptop that don't affect smartphones and tablets the same way, leaving more opportunities for repairs to be made economically. What's more, for some reason, people are more reluctant to throw out a laptop even though, in many cases, a laptop is cheaper than a tablet or smartphone. This factor also gives me some hope for the future of the repair industry.

In fact, I've found that some users want their laptop repaired even when faced with a major problem like a dead motherboard or a cracked screen. However, these are two repair scenarios that often result in the machine being scrapped due to the non-availability and cost of spare parts.

If I get a laptop in that has suffered a broken screen and it's less than a few years old, I usually advise the owner to make an insurance claim because the machine is too good to scrap and replacing the screen (assuming it's available) usually isn't cheap. In such cases, it's worth spending the money in order to keep the machine going and besides, that's what insurance is for.

Of course, it can all hinge on such things as the insurance excess and whether or not the part is available. As an example, as part of an insurance claim, I recently called the local

USERS OFTEN DIAGNOSE OVERHEATING PROBLEMS THEMSELVES...

agents of a certain well-known brand, asking for a quote and the expected delivery time for a replacement screen for a 6-year-old laptop. The insurance company subsequently agreed to my final quoted price and so I duly ordered the screen.

Now screens from this company usually take 3-5 days to arrive and when this one didn't show up after almost two weeks I called them and asked what was happening. I was somewhat surprised at their answer; they told me that while they did have a dwindling supply of spare screens for this model sitting in their warehouse, they wouldn't sell me one as they wanted to save their remaining stock for future warranty claims.

I don't know when they were planning on informing me of this about-turn but I thought it exceedingly poor service from one of the more respected brands around – especially considering there wouldn't be many laptops of that model and age still under any type of warranty. I'm guessing that this practice will become more prevalent as

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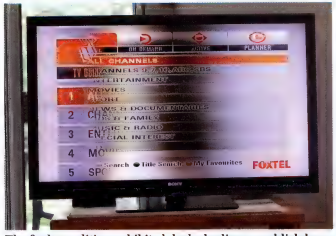


The fault condition exhibited dark shading, a reddish hue, picture smearing and ghosting.

This view shows the set stripped down to reveal the metal frame that runs around the outside of the LCD panel.

Sony KDL52Z5500 TV Set Repair

G. S. of Baulkham Hills, NSW recently ran into problems with a Sony KDL52Z5500 LCD TV. The set had an annoying fault when switched on from cold but would come good after about 30 minutes. Here's his story . . .

My Sony KDL52Z5500 132cm LCD TV set was purchased in 2009 and is a top-of-the-line 200Hz model that has given excellent performance. It cost around $3500 back then so you can imagine my dismay when it suddenly developed an intermittent heat-sensitive fault.

The problem started about a year ago and initially took the form of a narrow vertical flickering band on the lefthand side of the screen when the set was first switched on. This band was only a few centimetres wide and it always completely disappeared a few minutes after switch-on as the set warmed up.

This situation persisted for several months and then the problem took a turn for the worse. At switch-on, the entire lefthand side of the screen now took on a reddish hue with very dark shading, picture smearing and vertical ghosting. This problem also partially spilled over into righthand half of the screen (see photo).

As if that wasn't bad enough, the picture now took about 30 minutes (or more) to come good. What's more, during those 30 minutes, the picture was virtually unwatchable and that meant a frustrating wait in order to watch a program.

In the end though, it always came good until one day it didn't! During the middle of winter, the dark shading remained unchanged on several occasions, even after the set had been on for several hours.

After a year of putting up with this annoying problem, it was time to see if something could be done to fix it. I'd already spent some time researching the problem on-line and this indicated that the fault probably lay in the 'tabs' that connect the LCD to the driver circuits (typically on two long, narrow PCBs) that run along the top edge of the panel assembly.

As shown in one of the photos, these tabs are thin flexible strips, typically 40mm wide, and there are 16 of them in the Sony KDL52Z5500. They have multiple conductive tracks and are electrically bonded to edge pads that run along the front of the driver PCBs. The tabs then bend down through 90° to make the connections to transparent electrodes at the top of the LCD.

With repeated thermal cycling or if the screen is flexed (due to mishandling), the bonding contacts between the tabs and the PCB or to the LCD panel itself can sometimes become faulty. It's this that causes the dark shading and other problems such as ghosting and banding when the set is switched on from cold.

This type of fault often clears as the panel warms up, with the display suddenly coming good. In severe cases though, the fault remains no matter how long the set is left on.

Another possibility apparently is

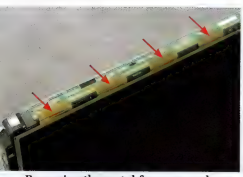
manufacturers save money by stocking less spare parts and as devices become more throwaway.

Laptop overheating

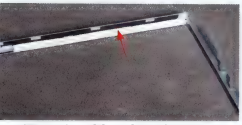
The more laptops I see the more I learn about their flaws and peculiarities. I've discovered that many share a common problem – overheating. Users often diagnose overheating problems themselves because they can feel the overly-hot air being expelled or can hear the fan roaring away when it used to be quiet.

Some models have a temperature monitor or fan-speed sensor that alerts users when things aren't right with the cooling system. This can also sometimes result in the machine being either shut down or prevented from booting until the problem is resolved. As a result, users often hit the web to find out how to fix the problem and, acting on on-line advice, often use a vacuum cleaner or air-compressor to suck or blow through any vents or apertures in the machine to clear away any lint or fluff.

While this sometimes clears the problem, it can actually make things



Removing the metal frame reveals the tabs (arrowed) which connect the driver boards to the top of the LCD.



Two strips of draught excluder were attached to the inside front edge at the top of the metal frame. These press against the flexible tabs at the top of the panel when the frame is replaced.

that the very fine tracks in the tabs can sometimes develop microscopic cracks, resulting in the tracks going high resistance or even open circuit.

So what can be done about it? Well, I found a video on YouTube at www.youtube.com/watch?v=B-mJX9TvAbc which describes an interesting cure. This involved removing the plastic dress frame at the front of the set and then the metal frame that goes right around the outside of the LCD to reveal the tabs. A strip of felt was then slid under the inside front edge of the metal frame in line with the offending tab and the frame replaced. When this was done, the felt strip applied pressure to the flexible tab and this fixed the problem (temporarily at least).

It was worth a try. After all, I had nothing to lose; if the KDL52Z5500 couldn't be fixed, it would have to be scrapped.

In order to remove the plastic dress frame, I first had to remove the back panel. That's best done with the set lying face down on a soft foam mattress or similar. A gazillion screws secure the rear panel in place and once they had all been removed, it was just a matter of lifting it free.

The next step involved undoing several screws to free the dress frame. Some of these screws are hidden behind the speaker pods and the stand, so these parts had to be removed as well. I then unplugged a couple of leads that run to small PCBs on the bottom section of the dress frame, unclipped the side control panel and re-attached the stand.

Next, I enlisted a family member to help to lift the set clear of the frame and stand it back upright again. That gave access to the metal frame that runs around the outside of the LCD. This frame was then removed by undoing nine small screws, unclipping it at the sides and carefully lifting it clear to reveal the tabs.

It was now time to fire the set up and see if I could locate the offending tab (or tabs). To do this, I jury-rigged the side control panel (which has the mains power switch attached to it), reconnected the speakers and applied power. The fault was present so I tried pushing against the eight lefthand tabs using the flat face of a wooden ruler whereupon the set suddenly came good.

It had only been on for a few minutes, so applying pressure to the tabs seemed to 'fix' the problem. What's more, I could make the problem come and go at will. The far lefthand tab seemed to be the one that was causing the trouble – release the ruler and the fault would appear; reapply pressure to this tab and it was gone.

That suggested a fix similar to that shown in the YouTube video. I didn't have any felt strips but I did have a roll of draught excluder, as used around windows and door frames. This is simply a 12mm-wide soft rubber strip with an adhesive backing and it appeared to be ideal for the job.

I cut an 800mm length, peeled away the backing and carefully affixed it to the inside front edge at the top of the metal frame, so that it would press against the tabs on the lefthand side. I was very careful not to cover any screw holes during this process – forcing a screw through the rubber could cause small fragments to come adrift and these could then find their way down between the LCD panel and its backlight panel. If that happened, there would be little chance of successfully retrieving them and the LCD would then display black fragment-shaped "blobs" at various locations.

While I was at it, I decided to also fit another 800mm length of draught excluder to the other side of the metal frame. That done, the power was switched off and the metal frame reinstalled around the LCD.

Applying power now brought up a perfect picture from cold. I subsequently tested the set for a several days before reinstalling the dress frame and the rear panel and putting it back into service.

It's worked perfectly for several months now but who knows how long that will last. With constant thermal recycling, it may only be a matter of time before the problem rears its ugly head again. The draught excluder "cure' may last two more days, another month, six months, two years or for the life of the set.

I'm not overly optimistic about it lasting but even if it's just a few more years, the work will have been well worthwhile.

worse by forcing lint build-up into the fan assembly, stalling it completely. On the other hand, these measures might clear some dust and allow the fan to work again but without a proper clean out, the fan won't run at full speed and the system will soon choke up again.

Of course the environment the machine is used in will make a big difference. Users in Christchurch have to deal with a very nasty form of dust caused by dried-out liquefaction. For those who don't know, liquefaction is a by-product of the more serious quakes we've had here. When the ground shakes, it can turn into liquid mud due to rising water (there are various demonstrations of this phenomenon on YouTube for those interested) and this liquid then rises to the surface, creating a thick, sometimes stinking mess that eventually dries out and turns into a particularly nasty, gritty dust. When our hot and blustery northest winds blow through town, the air is choked with this stuff and it gets absolutely everywhere, including inside electronic gear.

Laptops and desktop computers usually have several cooling fans and

Did RF Zap This QED A270 Amplifier?

Can a burst of RF energy from a microwave communications dish fry a stereo amplifier? G. M. of Pukekohe, NZ believes he has come across one such case . . .

During my 40-plus years in this profession, I have seen lots of strange electronic faults in audio and video appliances. In most cases, there is a logical explanation for the fault or failing that, a half-believable theory for the cause.

The job I am going to tell you about definitely fits the latter category, as there is no way to prove my theory as to what caused the fault. And since I wasn't present when it happened, I can only rely on the owner's version of events and add a couple of theories of my own to come to any conclusion.

The appliance in the hot-seat was a fairly old QED A270 integrated stereo amplifier, a minimalistic English design from about 20 years ago. The only controls on the front panel are a mains on-off switch, a volume control and two rotary switches to select the input source and a tape output.

QED are better known these days for their cables and interconnects but there was a period in their history when they manufactured some good-quality, well-respected hifi gear. Their design philosophy was to use discrete components rather than integrated circuits throughout the signal path and to keep the overall component count to a minimum in order to keep the signal as clean as possible.

In this particular case, the owner had been more than happy with the sound from the amplifier. It's teamed with a NAD CD player, Infinity bookshelf speakers and an old NAD tape deck and it had performed reliably over the years. In fact, it had been on my workbench just once since new for a fairly minor fault but now it was completely dead.

I called in to the lady's home to check the amplifier and confirm the symptoms. Sure enough, it was dead but I wasn't going to service it in the house, so I unplugged everything and removed it from the cabinet. As I did this, the owner recounted the events just before the amplifier stopped working.

I listened intently, if rather sceptically, to her explanation as to the cause of the amplifier's current state and nodded agreeably as you do to maintain good customer relations. What's more, I held my tongue, a skill that comes with maturity and stark memories of having put my foot in it on many prior occasions!

While I was there, I checked both speakers with an impedance meter to confirm their integrity. When an amplifier fails, it's often the hardworking output stage which succumbs and the speakers can be unwitting victims. If you are lucky, the fuse blows, sacrificing its worthless little self to save the life of the much more expensive speakers.

Sometimes, however, the fuse does not blow quickly enough or some well-intentioned do-it-your-selfer has replaced the original fuse with a higher-rated fuse to keep the party going. In this case though, my customer lived alone and her lifestyle and choice of music were hardly likely to lead to that scenario.

As luck would have it, the speakers were OK and I said I would phone her as soon as I had diagnosed the problem and could estimate the repair cost.

A couple of days later, I set the amplifier up on my workbench and popped the hood. The mains fuse had blown and a quick check with a multimeter confirmed the cause – three of the four output transistors had shorted!

Considering the age of the unit and the fairly obvious extent of the damage, I really didn't want to spend too much time on this job. I had to be as efficient as possible and avoid going too much beyond my minimum charge, otherwise there was a good chance the owner would reject my estimate and choose to replace the amplifier instead.

I didn't have a service manual so I searched on-line to see what I could find. I wanted to check how far the damage may have gone into the driver stages and a circuit diagram would help in this regard. Unfortunately, the search proved to be pretty fruitless – the best I could find was a couple of hand-drawn, almost illegible circuit diagrams, one of the front end and the other of the power amplifier stages.

Further research suggested that the original output devices were going to be hard to find. I wasn't keen on shoehorning substitute transistors into such an old amplifier and although other components may test OK right now, they may have been weakened by the output stage fault and fail sometime in the near future.

In short, it was going to be expensive to fix and could create a potential warranty issue. And that meant that the

these suck in air from the outside world. If this air is full of dust, the dust has to go somewhere and it usually ends up building up on the insides of the machine, collecting on anything in the way and especially components that tend to generate static electricity, which attracts the dust even more.

This is a recipe for disaster and possibly the reason I now see so many computers with overheating problems. Very few machines have any kind of air-filtering system and even those that boast such a feature usually only have a thin piece of foam rubber to act as a filter and this is about as effective as a colander at keeping dust out.

However, it's not a good to open up a desktop and vacuum it out or blow it out with compressed air. Of course this is what the DIY'ers often do but I always cringe inside when people tell me they've done this. That's because a vacuum cleaner often generates static electricity and this can easily destroy computer electronics. I've handled more than a few cases where the machine has simply stopped working after the owner has attacked it with a vacuum cleaner.

Blowing a PC out with compressed air can also cause problems, not just through static electricity (which can be generated by some compressor/air hose arrangements) but because there is often moisture in the compressed air and water and electronics don't mix. No doubt some people will claim they've cleaned things out this way for years without problems and while that may be true, the next time might be different.

If you are contemplating attacking your machine with compressed air or a vacuum cleaner, my advice is simple: don't do it. If you really must, then be aware of the dangers of static electricity and be careful. In particular, try

~CAN A BURST OF RF ENERGY FRY A STEREO AMPLIFIER?

amplifier really wasn't worth fixing.

So what did the owner tell me happened in those final moments before the amplifier failed? Well, her house overlooks the local rugby stadium which is about two hundred metres away as the crow flies. Apparently, the stadium was being readied for an international match to take place that afternoon and she was idly gazing through her window at the proceedings as she listened to her stereo.

Because the stadium is only rarely used for an event that's televised live, most of the camera equipment is set up on the day and microwave linked to the city studio. She was watching a small team of technicians setting up the mobile microwave antenna. As they did so, they swung the dish in her direction and at that very instant, her amplifier "shrieked" and died. That was enough proof – she was convinced that they were to blame.

Her description of the "shriek" was my first clue as to what caused the fault. The second clue was that both output stages would not normally fail at the same time. And the third clue was the coincidental timing of events.

Being a minimalistic design, the QED A270 amplifier had little in the form of RF protection in the signal path and the rough schematic I had obtained was enough to confirm this. While it had the usual RC filters to roll off the upper end of the audio spectrum to keep the amplifiers stable, these weren't enough to protect the unit when it was targeted with the narrowly-focussed beam of RF energy destined for a studio some 30km away.

I suspect that the output transistors took the brunt of the energy that was picked up by the speaker leads, which were acting as antennas. Either that or they were fed the rogue signal courtesy of some poorly-screened input cables. Of course, it's possible that no amount of RF protection could have saved it and any other amplifier would have suffered the same fate.

There's an old adage that says that the customer is always right and in this case, it was probably true. In the end, the owner wisely decided not to have the QED repaired and she is now enjoying her music courtesy of a very tidy secondhand Yamaha receiver that I had stored away for just such an occasion.

to keep the hose in contact with the computer's case to discharge any static and avoid contact with any internal hardware – static electricity can cause sparks that can leap considerable distances.

Note too that water condenses inside air-compressor tanks and it can either be purged from the system using a valve that's usually found on the bottom of the tank or removed using an in-line filter. Preferably, both methods should be used.

The only real way to deal with overheating laptops is to strip them down and clean them properly. Most laptops have carefully designed air channels and ducts to maximise airflow and any dust build-up in the airways or on the fan itself can cause the fan to slow down, in turn causing overheating and keeping the fan running. This also affects battery life; fans use power and having fans running more than necessary is something laptop designers want to avoid. In most cases, to access the heatsink and fan assembly, the machine must be stripped down.

You'd think there might be some consideration for cooling system maintenance but most manufacturers don't provide a handy access panel. This means that everything must be taken apart to get to the heatsink and fan. This makes for an expensive fix labour-wise, which is probably why people try to resolve it themselves.

Once access has been gained to the heatsink and fan assembly, it can be removed from the motherboard by undoing several screws and then unplugged. There are usually three or four tiny screws holding a thin metal ducting onto the plastic fan housing and this has to be removed as well. In addition, some strong fibre tape usually seals this ducting to the fins of the heatsink and this must be carefully removed if it is to be reused, though I usually replace it with aluminium "100-mile-an-hour" tape which is ideal for the purpose.

Once the ducting is clear, I then have total access to the fan itself and it is usually here that I find a block of lint similar in consistency to the doughnut-shaped one that builds up in the lint filter of a laundry hot-air dryer. It is this blob of lint that often gets pulled or forced back into the fan by vacuuming or blowing with an air-compressor. I use a soft artist's brush to clean each vane of the fan, taking care as age and heat can cause them to become brittle and replacement usually means buying the whole fan and heatsink assembly. I also generally lubricate the fan using light machine oil before reassembling everything.

If you have access to a power supply, it is good practice to power the fan up to check how it performs but extreme care should be taken to keep the voltage and current below the fan's electrical rating as they can burn out very easily.

Replace heatsink compound

Another important step is to replace the heatsink compound with suitable material. Many people simply reuse the heat transfer tape that's commonly fitted but this is a big "no-no" as it's usually damaged during removal or has become thinner with age. Heatsink compound can be purchased at any electronics store and as you only need a smidgen, it lasts for ages so there is no excuse for re-using old worn-out stuff.

After reinstalling the fan/heatsink assembly, I give the inside of the case a good brush down and a blow-out with dry, filtered compressed air before putting everything back together. Done

properly, this gives the laptop a new lease of life and the fan should keep things cool for years to come, until the dust builds up again.

Remote spotlight repair

A remote control system that won't control something can be very frustrating. This one would turn a light on but wouldn't turn it off again until G. B. of Essendon, Victoria tracked the fault down, Here's what happened . . .

A few years ago, my wife and I built a new house and in the course of events, I neglected to consider lighting for the back yard. The ideal position for a couple of floodlights was high on the garage wall, with another unit positioned behind the garage where the rubbish bins are located. That way, they would light up the way to the bins and the clothes line.

Unfortunately, there were no spare conduits between the garage and the house to run some cables. Then one day, while walking around Bunnings pondering this problem, I spied some remotely-operated power points (manufactured by Kambrook) and a remotely-operated spotlight from Arlec. I purchased these and duly installed them. The remote power point (installed inside the garage) was used to switch a double 200W spotlight that lights the backyard, while the Arlec single-spotlight unit was connected directly to an outdoors-type power point located in the rubbish bin area.

Because they are remote controlled, these lights can all be switched on and off from within the house. However, the supplied remotes were ditched in favour of my own home-grown controller consisting of a PIC16F684 chip, a Jaycar 434MHz module and four buttons fitted into a GPO face plate.

The Arlec unit uses a PT2262 remote control encoder, while the Kambrook unit uses a different chip (the number had been ground off). This meant that I had to 'reverse engineer' the Kambrook unit to figure out the protocol. Anyway, I got it all to work and all was OK for about three years until, one day, the Arlec unit would turn on OK but would require several switch presses to get it to turn off. Eventually, it failed to turn off altogether and required a manual switch off and on again to reset it.

This went on for about six months and into the middle of winter. In the end, the trips back from the bins in the dark (and sometimes the rain) were starting to get a bit tricky, so I decided I'd better do something about the problem.

The Arlec unit has a weatherproof enclosure attached to the light to house the PCB and I needed to take a look at this. First, I unplugged the unit from the outdoor power point, then gave the rusted hinge a few squirts of WD40 so that I could spin it around to get access to the PCB enclosure. Four screws and a rubber gasket hold the enclosure's cover on and these were easily removed.

I fully expected that the problem would be corrosion caused by a leak around the gasket but the back of the PCB showed no signs of any such problems. Nor was there any sign of water ingress into the enclosure. That meant that the PCB would now have to be removed so I took a photo of the connections and drew a sketch as well, just for good measure.

The single-sided PCB is freed from the enclosure by undoing two screws. Removing it reveals the 230VAC connector, which also carries the connection from the relay (mounted on the PCB) for the spotlight.

The circuit itself derives its power directly from the 230VAC mains via a 1µF 250V mains-rated capacitor connected to the Active, so the whole circuit is potentially lethal. There is a 220kΩ resistor in parallel with the 1µF 250VAC capacitor and a 4.7kΩ resistor in series with the capacitor. There is also a 4.7kΩ resistor in the Neutral line.

Both these 4.7kΩ resistors feed a bridge rectifier and across this rectifier is a 470µF 16V electrolytic and two back-to-back 12V zener diodes for over-voltage protection. The rest of the circuit consists of the PT2262 decoder, a relay driver transistor and a few other bits and pieces.

Once the PCB had been removed from the unit, I set it up on the workbench. I connected 12V directly across the AC input part of the bridge rectifier rather than wire it up to the 230VAC. As mentioned, the circuit is normally directly powered from the mains and cannot be worked on safely when connected in this manner.

Anyway, on the bench it seemed to work fine. I used the original remote fob that was supplied with the unit and it would switch on and off every time. I then checked the PCB more closely with a magnifying glass but couldn't detect anything irregular so I removed the electrolytic capacitors and tested them. They all checked out fine so I reinstalled them and tested all the diodes. These also checked out OK, so I then decided that the best thing to do would be to reconnect it to the enclosure and give it another test. Perhaps all my messing around had somehow fixed it (eg, by resoldering a bad solder joint).

Once it was reconnected, I used the supplied remote fob to test it in-situ, just to clear my home-grown unit. The fault was still there; it would switch on fine but it wouldn't switch off, no matter which remote fob/switch was used.

I removed the PCB again, set it up on the workbench again and turned my attention to the 1µF 250VAC mains capacitor. When I'd previously tested it, it measured 0.22µF instead of 1µF, about a quarter of its original value. It all fell into place then: the Vcc supply line to the PT2262 must be dropping below its minimum level when the relay operates, even though the latter only draws 30mA. This would be caused by the increased impedance of the 1µF capacitor not supplying enough power for the circuit when the relay is on.

Conversely, with the relay off, there is only minimal current draw and so the Vcc rail is maintained at the proper level, allowing the unit to switch on. Fitting a new capacitor fixed the problem. So I really should have been much more suspicious of its low value when I first tested the capacitor. SC

Servicing Stories Wanted

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Programmable mains timer with remote switching

Remote-controlled mains switches are very convenient but what if you could add a versatile easy-to-program timer to one of these units? Well, now you can. This Remote Switch Timer can be programmed to switch the power on and off after a set period or to switch the power on and off at set times.

By JOHN CLARKE

MAINS TIMERS are ideal for switching appliances on or off at predetermined times. Their complexity ranges from simple mechanical timers with a synchronous motor and switch actuator cams through to complex menu-driven fully-electronic timers which tend to have fiddly buttons and can be difficult to program. However, none have the advantage of remote control, whereby the timer is remote from the actual mains-switched power socket.

To give an example, say you have an appliance in your garage that you want to control with a mains timer. Wouldn't it be nice if you could program and control the timer without having to be in the garage? This idea can be extended to a lot of applications.

To meet this need, we've devised this "Remote Switch Timer". It's designed to work with just about any commercially-available remote control mains socket (provided the hand-held remote is powered by a 12V battery). Basically, it interfaces with the remote's PCB and provides the extra timing functions. The remote then automatically switches the mains socket on and off, as required.

As shown in the photos, the Remote Switch Timer is housed in a plastic box, along with the PCB from the remote. It has 10 pushbutton switches and a 2-line LCD which has a dimmable backlight for night-time use. The front-panel buttons are used to program and control the unit.

Remote control mains sockets

For those unfamiliar with these devices, a remote control mains socket consists of a mains plug and piggyback socket, together with a relay and UHF receiver inside the plastic housing. It is controlled using a UHF hand-held remote control which is used to switch the mains socket on and off.

Both 3-channel and 8-channel

The Jaycar remote controlled mains switch comes with a 3-channel hand-held remote. The MS-6142 comes with a three mains sockets, while the MS-6145 has one socket.

The Altronics A0340 has an 8-channel remote control and is supplied with a single mains socket. Additional mains sockets can be purchased separately.

remotes are typically available and these come either with a single socket or with a number of sockets. Alternatively, the additional sockets have to be purchased separately. The remote controls each socket individually and it's just a matter of either using a learning procedure to set the socket's channel number of setting a channel switch on the rear of the socket.

The Altronics A0340, Jaycar MS-6145 and Jaycar MS-6142 are typical of the units currently available.

How does it work?

The Silicon Chip Remote Switch Timer is designed to activate any pair of on/off switches on the remote control. It does this by controlling two small relays which have their contacts wired across the desired on and off switches on the remote's PCB.

Basically, it's just a matter of removing the remote's PCB from its case and housing it together with the Remote Switch Timer inside a plastic utility case. The two are then wired together and powered from an external 12V DC plugpack and an optional internal 9V back-up battery.

As well as using the new automatic timing functions, you can still manually control the mains socket using separate On and Off pushbuttons on the Remote Switch Timer. Alternatively, another hand-held remote can be used.

In preset-time mode, the Remote Switch Timer is used to send an on or off signal to the remote mains socket after a set period of time. You simply program when you want the socket to switch on or off and then press the Set/Start button. The timer then automatically switches after the preset time, which can range from a minimum of one minute to a maximum of 255 hours and 59 minutes (that's more than 10 days!).

During the time-out period, the displayed time decreases by one every minute until the timer reaches zero. The relay for that timer function then closes and the UHF signal from the remote is sent to the mains socket.

To set the time-out period, you first select either the On or Off timer using the Next pushbutton. The separate Up and Down hours and minutes pushbuttons are then used to set the required timing period.

If you want more complexity, the Remote Switch Timer can use both its timers. One timer can be set to turn the mains socket on after a preset time, while the other can be set to then turn it off (or vice versa). In addition, the On and Off pushbuttons can be used to set the initial status of the remote control mains socket; ie, you can start with the mains power on or off.

Default timing cycle

The default timing cycle for the unit is for it to run once only. This is where the timers are set to their required values and decrease over time until they reach zero. Once a timer has counted down to zero, there is no more control from that timer unless it's set to a new value.

Note that the timer will just show dashes when the time-out is zero.

The default setting can be changed from "once only" to "repeat". This is where the timers are returned to their original settings after both timers have timed out.

As an example, let's say that you've set the On timer to two minutes and the Off timer to three minutes. This means that after two minutes, the On timer will have counted down to zero and sent an "on" signal to the mains socket to turn on the power. The Off timer now continues to count down and when it too reaches zero (ie, after one minute more), an "off" signal will be sent to the mains socket. Both timers will then be reset to their original 2-minute and 3-minute settings and so the cycle repeats every three minutes.

The on and off timers for this countdown style of timing are called the "ON IN" and "OFF IN" timers (ie, on in a certain period and off in a certain period). The once only and repeat timer options are predictably named "ONCE ONLY" and "REPEAT".

This style of timer is quite useful (and simple to use) for many timer applications. However, for even more flexibility, a "real-time" timer mode is also included. This is similar to setting an alarm clock and allows you to set the time of day for the on/off switching to occur.

Parts List

1 double-sided, plated-through PCB, code 19112141, 104 x 76mm
1 front panel PCB, code 19112142, 157 x 94mm* OR
1 front panel label, 144 x 84mm*
1 UB1 plastic utility case, 158 x 95 x 53mm*
6 M3 x 9mm tapped spacers*
1 LCD module with backlighting (Altronics Z-7013, Jaycar QP-5512)
1 UHF remote-controlled mains switch with 12V powered remote controls (eg, Altronics A0340, Jaycar MS-6145, MS-6142)
2 SPST DIP 5V reed relays (Altronics S4100A, Jaycar SY-4030) (RLY1,RLY2)
1 4MHz low-profile crystal (HC49US case) (X1)
10 click-action pushbutton PCB switches (white) (Jaycar SP-0723, Altronics S1099)
1 12V DC plugpack (100mA or greater)
1 16-way SIL pin header with 2.54mm pin spacing
1 panel-mount DC socket (2.1 or 2.5mm to suit plugpack)
4 2-way polarised headers (2.54mm pin spacing)
4 2-way polarised header plugs (2.54mm pin spacing) (CON1-CON4)
12 M3 x 5mm machine screws (2 preferably countersunk for the rear of the box)
1 100mm cable tie
1 400mm length of medium-duty black hook-up wire
1 200mm length of medium-duty red hook-up wire

Semiconductors

1 PIC16F88-I/P microcontroller programmed with 1911214A.hex (IC1)
1 LP2950ACZ-5.0 low-dropout 5V regulator (REG1)
1 BC337 NPN transistor (Q1)
6 1N4148 diodes (D1,D2,D4-D7)
2 1N4004 1A diodes (D3,D8)

Capacitors

2 10µF 16V PC electrolytic
1 100nF MKT polyester
2 33pF C0G (NP0) ceramic

Resistors (0.25W, 1%)

1 100kΩ 1 330Ω 0.5W
1 10kΩ 2 100Ω
1 2.2kΩ
1 10kΩ miniature horizontal trimpot (VR1)

***Alternative enclosure parts**

1 sealed polycarbonate case with clear lid 115 x 90 x 55mm (Jaycar HB-6246 or similar)
1 front panel label, 103 x 78mm
4 M3 x 12mm tapped spacers

Optional parts for battery back-up

1 9V battery snap with lead (Jaycar PH-9232, Altronics P 0455)
1 9V battery (522/6LR61)
1 9V U-clamp battery holder (Jaycar PH-9237, Altronics S 5050)
1 2-way polarised header & plug (2.54mm pin spacing) (CON5)
1 M3 x 6mm machine screw
1 M3 nut

In order to do this, a real time clock is required and the one used here is in 24-hour format.

Real-time switching

For this mode, we call the real-time timers "ON AT" and "OFF AT" (ie, on at a certain time and off at a certain time). You can set either one timer or both. The timers are also in 24-hour format and are compared against the time on the clock. When the clock and timers match, an on or off signal is sent to the mains socket.

Note that in this mode, the timer values do not change during the time-out period. Instead, they are simply compared with the clock for a time-out match.

Note that a 00h:00m setting for either timer will show as dashes on the LCD and there is no on or off switching for this setting. 00h:00m also corresponds to midnight, so it is not possible to have the timer switch at precisely midnight. However, switching times one minute before (23h 59m) and one minute after midnight (0h 1m) are possible.

This rather minor shortcoming allows for simplified timer operation because it doesn't require an extra selection as to whether you want a timer to be operational or not.

There are two possible settings for real-time switching: (1) where the sequence occurs once only; and (2) where the on and off cycle is repeated each day. As before, these options are called "ONCE ONLY" and "REPEAT".

For the once only selection, the timer will revert to zero (with the LCD showing dashes) once that timer has matched the clock. For the repeat selection, the timer will remain at its time setting so that it can repeat the switching sequence each day.

Clock accuracy

The long-term timing accuracy depends on the accuracy of the crystal timebase used in the Remote Switch Timer. This in turn is dependent of the crystal tolerance and on temperature variations throughout the year.

For a standard ±50ppm crystal, the clock could be fast or slow by up to 130s (ie, two minutes & 10 seconds) over a period of 30 days. However, the timing accuracy can be easily adjusted by changing a value in the software that runs in the PIC microcontroller used in the Remote Switch Timer.

Basically, the can be adjusted to run faster or slower in 1ppm steps, up to a maximum of ±99ppm. A 1ppm change represents about 2.6s in 30 days, while the 99ppm maximum adjustment corresponds to 256s in 30 days.

Adjusting the clock accuracy may be necessary if you want the "ON AT" and "OFF AT" timers to switch the unit at certain times of the day. However, it will not usually be necessary for the "ON IN" and "OFF IN" timers which are used to switch the unit in a certain time period.

Battery back-up

An option is to include a battery back-up for the Remote Switch Timer. That way, all settings will be retained and timing will continue in the event of a black-out or if mains power is removed from the unit.

Of course, the mains socket will not be powered in the event of a blackout and so it will not respond to any on or off signals from the unit. However, when power is restored, the last on or off signal is sent again after a short delay. That way, the mains socket will switch to the required setting for the present time.

Note that the backlighting for the

LCD module is switched off to conserve the battery when the unit is running from battery power alone.

Without battery back-up, the Remote Switch Timer will reset with all timers set to zero when a black-out ends. In addition, the mains socket will be reset with the power off.

In summary, it's an incredibly versatile unit that's easy to program. It should cover a very wide range of timing applications.

Circuit details

Take a look now at Fig.1 for the circuit details of the Remote Switch Timer. It's quite simple and is based on a PIC16F88-I/P microcontroller (IC1), an LCD module, a couple of miniature relays, 10 pushbutton switches and a few other parts.

Most of the complexity is hidden inside the software that's programmed into IC1. This allows the micro to monitor the switch inputs and drive the LCD module and relays according to the actions required by the switches and internal timers.

IC1's RA2, RA3, RA4 & RB0 data lines send character data to the LCD module. In addition, the RA1 & RB7 lines drive the Enable (EN) and Register Select (RS) inputs. The LCD is set to run using four bits of data to save on outputs from IC1. The necessary data bits are sent to the LCD as two separate transfers, to make up the eight bits necessary to fully drive the display.

The RA2, RA3, RA4 & RB0 lines also drive a matrix based on pushbutton switches S1-S10 and diodes D4-D7. To check if a switch is closed, the RA2, RA3, RA4 & RB0 lines are driven low and the RB2, RB4 & RB5 inputs monitored. These latter inputs are normally pulled high (to +5V) via internal pullups but one of these inputs will go low (ie, close to 0V) if a switch is closed.

When a low is detected, the RA2, RA3, RA4 & RB0 lines are taken high again and then taken low one at a time while IC1 continues monitoring RB2, RB4 & RB5. This allows the micro to determine which switch button is being pressed. For example, if S3 is closed, this will be detected when RA4 goes low and in turn pulls RB4 low.

Diodes D4-D7 are there to prevent shorts between the RA2, RA3, RA4 & RB0 lines if two switches are pressed at the same time. Shorts between these lines would not only affect switch detection but would also affect the drive

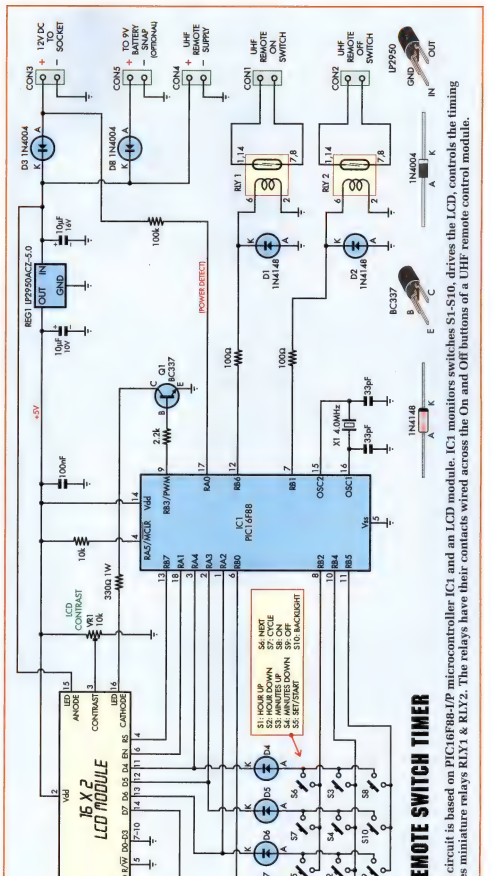


Fig.1: the circuit is based on PIC16F88-I/P microcontroller IC1 and an LCD module. IC1 monitors switches S1-S10, drives the LCD, controls the timing and drives miniature relays RLY1 & RLY2. The relays have their contacts wired across the On and Off buttons of a UHF remote control module.

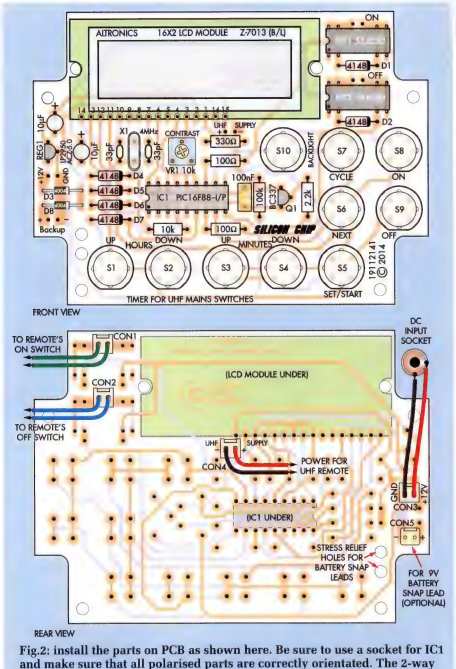


Fig.2: install the parts on PCB as shown here. Be sure to use a socket for IC1 and make sure that all polarised parts are correctly orientated. The 2-way header sockets (CON1-CON5) are the only parts that mount on the rear of the board.

signals to the LCD and cause corrupted characters to be displayed.

Ports RB1 & RB6 drive relays RLY1 & RLY2 via 100Ω resistors. The NO (normally open) contacts of the relays go to CON1 & CON2 and these in turn are wired in parallel with the ON and OFF switches respectively on the UHF remote's PCB. Diodes D1 & D2 are there to prevent damage to RB1 & RB6 by clamping the back-EMF generated by the coils when the relays switch off.

The 100Ω resistors in series with the relay coils also help protect IC1's RB1 & RB6 outputs. They are not needed in normal operation but will limit the back-EMF current from a relay coil if its associated diode fails or develops a dry joint connection.

Timing

A 4MHz crystal (X1) between pins 15 & 16 of IC1 is used to provide an accurate reference for the timing oscillator. It's loaded with fixed 33pF capacitors to ensure it starts correctly.

Normally, the crystal would be trimmed to a precise 4MHz using a trimmer capacitor in place of one of the fixed values. However, without suitable calibrated test equipment, it's not possible to accurately adjust the trimmer without a great deal of trial and error. As a result, as previously stated, we chose to use a software adjustment procedure instead.

If the 4MHz crystal is precisely on frequency, the program runs at exactly 1MHz. The software uses a counter (Timer1) that overflows after a count of 40,000 or after 1/25th of a second if the clock frequency is precisely 1MHz (ie, 25 of these 40,000 counts will take 1s).

If the crystal runs too fast or too slow, it's just a matter of altering the 40,000 number used in the counter to provide the correct 1s period. For example, for a 1ppm adjustment, the number for Timer1's overflow counter must either be 40,001 (ie, one more) if the crystal is too fast or 39,999 (ie, one less) if the crystal is too slow.

Note that this change is only done for one of the 25 overflow counts that make up one second for Timer1. The remaining 24 counts still use 40,000 as the count.

As stated, the overall adjustment range is from -99ppm to +99ppm. In operation, the software then adds or subtracts the ppm correction value from 40,000 in order to compensate for the crystal frequency.

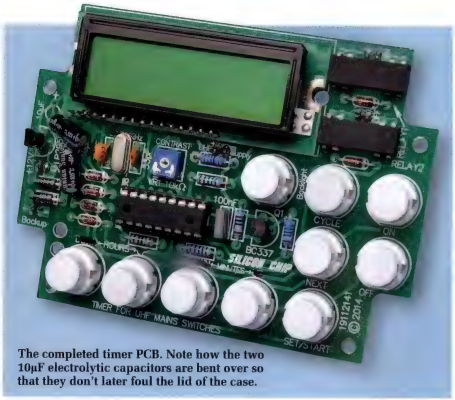
The overflow ppm adjustment is done via the front-panel switches as described later, with the setting shown on the LCD. The correction required is determined by comparing the time of the Remote Switch Timer against a known accurate clock over a set period. Each 2.592 seconds in 30 days that it is off is equivalent to 1ppm.

Note that the clock on the Remote Switch Timer shows the seconds, so that the clock's accuracy can be checked. The timing functions, however, are only to the nearest minute.

Backlighting

Backlighting is provided for the LCD so that the timer can be used in the dark. This can be adjusted in 16 steps from fully off through to full brightness by pressing the Backlight pushbutton (S10). This brings up the backlighting value which is shown as a number ranging from 0-15, with 15 being full brightness. A bargraph is also used to show the brightness setting.

For brightness levels between 1-14, the backlight LEDs are driven using PWM (pulse width modulation). Pin 9 (PWM) of IC1 provides the PWM



The completed timer PCB. Note how the two 10µF electrolytic capacitors are bent over so that they don't later foul the lid of the case.

waveform and this drives the cathodes of the backlight LEDs via transistor Q1 and a 330Ω current-limiting resistor.

For level 0, there is no drive to the LED cathodes (Q1 permanently off) and for level 15, the LEDs are continuously driven (Q1 permanently on). At other levels, the duty cycle of the PWM pulse determines the LED brightness. At half brightness, for example, the LEDs are switched on and off via Q1 using a 50% duty cycle.

The PWM frequency is 66.66kHz, so the on and off switching of the LEDs will not be noticeable.

The contrast of the LCD module is adjusted using VR1. It's just a matter of tweaking VR1 to suit.

Power supply

The Remote Switch Timer is normally powered from a 12V DC plugpack supply connected to CON3. Diode D3 provides reverse polarity protection and the nominal 11.4V supply rail is then filtered using a 10µF capacitor and used to power the backlight LEDs in the LCD module.

The 11.4V rail is also fed to low-dropout regulator REG1. This produces a regulated 5V rail to power microcontroller IC1, the LCD module and the remaining circuitry.

The optional 9V back-up battery is connected to CON5. Diode D8 provides reverse polarity protection and both it and D3 isolate the two supplies.

IC1's RA0 input (pin 17) monitors the 12V supply line from CON3. If this goes to 0V but IC1 is still powered via the back-up battery, the software detects this loss of 12V power and switches off the backlight. When the 12V is subsequently restored, this is detected by RA0 and the last ON or OFF signal is resent to the remote PCB by turning on the appropriate relay.

In practice, the ON or OFF relay is activated about 3s after power is restored and remains on for around 900ms. This 3s delay gives enough time for the remote control circuit to power up and for the companion mains socket to power up if there has been a blackout.

Construction

All the parts (except for the UHF remote) are installed on a PCB coded 19112141 and measuring 104 x 76mm. Fig.2 shows the parts layout on the PCB.

Begin by installing the resistors and diodes. Table 1 shows the resistor colour codes but we recommend that you also check each one using a DMM before installing it. Be sure to install the diodes with the correct polarity.

REG1 and Q1 are next on the list. These two devices look the same, so be careful not to get them mixed up. Once they're in, install an 18-pin socket for IC1, with the notched end towards D5.

Follow with the capacitors. The two 10µF electrolytics must be installed with the polarity shown and bent over so that they lie flat against the PCB, so that they later sit below the top edge of the LCD module (see photo). The ceramic and MKT capacitors can be mounted either way around.

Crystal X1 and trimpot VR1 can now go in, followed by the two relays. Note that each relay must be installed with its notched end towards the LCD.

Now for the LCD module. This is mounted using a 16-way SIL pin header at the bottom lefthand edge. Begin by fitting the header in place with its short pins going into the PCB. Solder these pins, then fit the LCD module over the longer pins and push it all the way down before soldering these pins as well.

The 10 pushbutton switches can now be installed. These go in with

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
100nF	0.1µF	100n	104
33pF	NA	33p	33

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	1	2.2kΩ	red red red brown	red red black brown brown
❑	1	330Ω	orange orange brown brown	orange orange black black brown
❑	2	100Ω	brown black brown brown	brown black black black brown

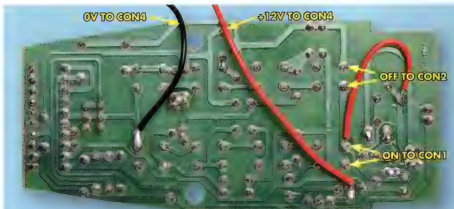


Fig.3: here's how to make the connections to the Altronics UHF remote PCB. The red and black leads shown are all part of the original wiring.

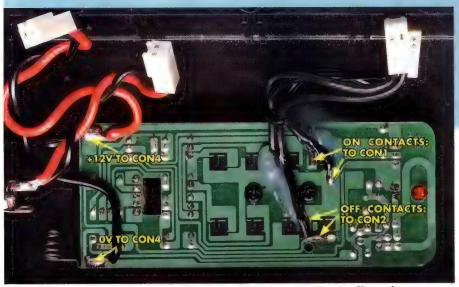


Fig.4: the wiring connections to the Jaycar UHF remote. You will need to scrape away the solder masking from some of the tracks before soldering the leads.

their flat sides orientated as shown and must be pushed all the way down before soldering their pins.

The PCB assembly can now be completed by installing CON1-CON5. These polarised 2-way headers are installed on the rear of the PCB with their plastic tabs orientated as shown in the bottom diagram of Fig.2.

Wiring the header sockets

The header sockets are wired by crimping the wires into the crimp lugs and then pushing them into the socket shell. These wires can all initially be about 100mm long and you will need to use red and black leads for CON3-CON5 as shown. The leads for CON1 & CON2 run to the ON & OFF switches on the remote PCB, so their polarity is unimportant.

Test & adjustment

Before applying power, make sure that IC1 is out of its socket and that all polarised parts are correctly orientated. That done, apply 12V DC to CON3 and use a DMM to check the supply between pins 14 & 5 of IC1's socket. This should be somewhere between 4.75V and 5.25V.

If this is correct, switch off, install IC1 (notch towards D5) and reapply power. The LCD should now show characters. Adjust VR1 for best contrast, then switch the backlighting on by pressing the backlight button (S10). Check that brightness can be adjusted by holding S10 down (the adjustment direction changes each time you press S10).

Now press the On button (S8). A click from the ON relay should immediately be heard and the top line of the LCD should display "ON". Similarly, pressing the Off button should briefly turn the OFF relay on and cause "OFF" to be displayed on the bottom line of the LCD.

If the unit passes these tests, then it is almost certainly fully functional and it can be installed in a case, along with the remote's PCB module. If it doesn't work, go back over the PCB and check carefully for incorrect component values, incorrectly orientated parts and missed solder joints.

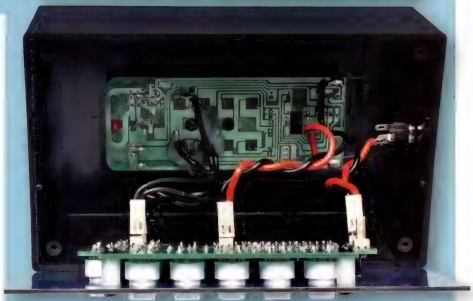
The timer PCB is mounted on spacers on the rear of the front panel and is secured using eight M3 x 6mm machine screws.

Case installation

The PCB can be installed either in a UB1 plastic utility case (158 x 95 x 53mm) or in a sealed polycarbonate case with a clear lid (115 x 90 x 55mm). A front panel PCB coded 19112142 and measuring 157 x 94mm can be used with the UB1 box. This PCB replaces the plastic lid and comes with all holes drilled and screen-printed lettering. It's available from the SILICON CHIP PartShop, as is the main PCB.

Alternatively, a label measuring 144 x 84mm can be used with the existing lid on the UB1 box. A front panel label measuring 103 x 78mm is also available for the polycarbonate box. These labels can be downloaded in PDF format from the SILICON CHIP website and printed out.

You will need to print out two copies – one onto plain paper for use as a drilling template and another onto photo paper to use as the front-panel label. The labels show the screw-mounting locations for the PCB on the lid, along with the switch locations. A rectangular cut-out for the LCD surround will also be required for the



Above: these two views show the inside of the unit with all wiring completed (Jaycar remote PCB used, no back-up battery fitted). Use neutral-cure silicone or hot melt glue to hold the wiring to the remote PCB in place.

Dataflex & Datapol Labels

(1) For Dataflex labels, go to: www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_60&products_id=335

(2) For Datapol labels go to: www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_55&products_id=326

UB1 box but this isn't necessary for the polycarbonate case with the clear lid.

The PCB mounting holes should be drilled to 3mm, while the switch holes should be started using a pilot drill and then carefully enlarged to 10mm using a tapered reamer. The rectangular display cut-out can be made in the UB1 box lid by first drilling a series of holes around the inside perimeter, then knocking out the centre piece and filing to a smooth finish.

Once the holes have been drilled, the front-panel label can be affixed to the lid using a suitable glue or neutral-cure silicone. Alternatively, you can print onto an A4-size synthetic "Dataflex" sticky label if you have an inkjet printer or onto a "Datapol" sticky label if you have a laser printer. This can then be trimmed to size and affixed to the base of the case using the label's self-adhesive backing.

Dataflex and Datapol labels are

Features & Specifications

- **Power:** 12V DC at 30mA
- **Current:** 30mA with full backlighting; 3mA with backlighting off
- **Battery backup current:** typically 3mA
- **On & Off IN:** adjustable from 0h 0m to 99h 59m in 1-minute steps
- **On & Off AT:** adjustable from 0h 0m to 23h 59m (0h 0m shown as --:-- and timer is off)
- **Real Time Clock:** 24-hour format with hh:mm:ss
- **Crystal tolerance compensation:** ±99ppm
- **Dimming:** off to full brightness in 16 steps; 66.66kHz PWM (pulse width modulation).

Instructions For Using The Remote Switch Timer

The very first time the Remote Switch Timer is powered up, the backlighting will be off and the timer will be in the ON IN and OFF IN Once Only mode (Fig.5). Two lines will be displayed on the LCD, with the top line showing **ON IN**"---:--" and the lower line **OFF IN ---:--** The inverted commas in the first line show that the ON IN time can be changed using the Hours and Minutes Up/Down buttons.

The dashes mean that the timer is off. Note that three dashes are allocated for the hours position and two for the minutes. This represents three digits for the hours and two for the minutes. The settings can be up to 255h 59m.

Note that if you want an hour value above 127, it's quicker to reach this by pressing the down button to count back from zero hours.

Pressing the Next button (S6) moves the inverted commas to the second line. The LCD then shows **OFF IN** "---:--" and the hours and minutes for this setting can again be adjusted using the up and down buttons.

Depending on the above setting, you also need to select whether the mains switch is initially on or off. That's done by pressing the ON or OFF button (Fig.7). Pressing the Set/Start pushbutton (S5) then starts the timing, with the colon between the hours and minutes digits flashing and the inverted commas off.

Pressing the Set/Start button again stops the timing or you can do this to change the ON IN or OFF IN values. Note that timing will not begin unless the colon is flashing.

Changing the cycle

To check which cycle you are running or to change the cycle, press the Cycle button (S7). The current cycle will be displayed and this will initially be ON/OFF IN Once Only. Other selections are ON/OFF IN Repeat, ON/OFF AT Repeat and ON/OFF AT Once Only (Figs.8-10).

You can just view the setting, by pressing the Cycle button for up to 10s. Pressing it for longer than 10s lets you move to the alternative settings. After 10s, the cycle indicator will be shown and the unit will count down from 10 to 0. When zero is reached, the cycle changes to the next selection. It's just a matter of holding the Cycle button down until the required cycle is reached.

The hours & minutes settings for the ON/OFF AT cycle are achieved in exactly the same manner as for the ON/OFF IN cycle, with the Next pushbutton again used to select the OFF AT timer.

Adjust ppm correction

Pressing the Next button after OFF AT has been selected brings up the "Adjust ppm" correction value on the top line and the real time clock on the bottom line (Fig.11). A right arrow shows which line can be changed using the Hours and Minutes buttons. As before, pressing the Next button cycles through the selections.

The ppm setting is initially zero but can be changed using either the Hours or Minute buttons to ±99 maximum. A positive value speeds up the clock, while a negative value slows it down. A 1ppm change represents about 2.6s in 30 days or about 1s every 11.5 days. The 99ppm maximum adjustment corresponds to 256s in 30 days or about 8.53s per day.

The real-time clock runs continuously and its time can only be changed in Set mode. The seconds are reset to zero each time the hours or minutes are changed, allowing the clock to be easily synchronised with another clock. Note that only the clock is shown in run mode, not the ppm crystal correction value.

In practice, it's all very straightforward and is far less complicated than it sounds. A few minutes spent playing with the buttons will familiarise you with the way it works.

What's remembered?

If you don't use the battery back-up, then the Remote Switch Timer will power off in a blackout or when you disconnect power. When power is restored, the timers will be at zero (showing dashes) and the clock will initially begin from zero (midnight). However, the cycle setting, backlight dimming level and crystal ppm correction value will all be restored to their values before power went off.

By contrast, with battery back-up, the clock and timers will continue to run and their settings will not change. In addition, the last ON or OFF setting required for the remote mains socket will be remembered and re-sent after a 3s delay when power is restored.

available from www.blanklabels.com.au and sample sheets are available on request to test in your printer – see panel.

Once the label is in position, the Remote Switch Timer PCB can be attached to the rear of the lid using tapped spacers and M3 x 5mm machine screws. M3 x 9mm spacers are used for the UB1 box, while M3 x 12mm spacers are used for the polycarbonate case so the LCD module sits inside the clear lid (this eliminates the need for a display cutout).

Alternatively, if you are using a PCB front-panel with the UB1 box, it's simply a matter of mounting the PCB on M3 x 9mm spacers.

DC socket & battery holder

An 8mm-diameter hole has to be drilled in the lefthand end of the case for the panel-mount DC socket. This can then be fitted in position

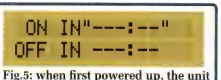


Fig.5: when first powered up, the unit is in ON IN and OFF IN Once Only mode. The inverted commas indicate that the ON IN time can be set using the Hours and Minutes buttons.

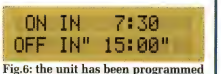


Fig.6: the unit has been programmed here to turn on in 7.5 hours and off after 15 hours. Pressing the Set/Start button starts the timers.

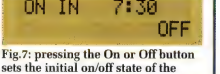


Fig.7: pressing the On or Off button sets the initial on/off state of the remote mains socket.

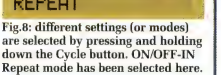


Fig.8: different settings (or modes) are selected by pressing and holding down the Cycle button. ON/OFF-IN Repeat mode has been selected here.

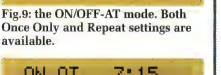


Fig.9: the ON/OFF-AT mode. Both Once Only and Repeat settings are available.

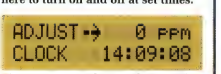


Fig.10: the unit has been programmed here to turn on and off at set times.

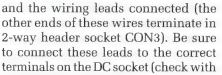


Fig.11: pressing the next button after OFF AT has been selected lets you adjust the clock and set the time.

and the wiring leads connected (the other ends of these wires terminate in 2-way header socket CON3). Be sure to connect these leads to the correct terminals on the DC socket (check with a DMM if necessary).

As stated, the back-up battery is optional. If you wish to use it, it's just a matter of connecting a 9V battery snap to CON5 and installing a 9V battery holder. Before soldering the battery snap leads, loop them through the adjacent strain relief holes. The holder can be secured to the base or to one side of the case using an M3 x 6mm machine screw and nut.

Remote control PCB

Before removing the remote's PCB module, the remote control mains socket (either from Jaycar or Altronics; see parts list) should be set to operate as described in the instructions. This will familiarise you with the way the units works and allow you to set the channel number and test its operation.

Once you've done that, the hand-held remote can be disassembled. The Jaycar remote has one screw located beneath the battery cover and when removed, the two halves of the remote case can be cracked open along the sides with a screwdriver. By contrast, the Altronics remote has two screws under the battery compartment lid and removing these allows you to split the case.

It's then just a matter of removing the remote PCB and connecting the leads from CON1, CON2 and CON4. CON1 is wired across the ON contacts for the selected channel, CON2 across the OFF contacts and CON4 to the UHF remote's supply rails. Figs.3 & 4 show the details.

On the Jaycar remote, it will be necessary to scrape away the solder masking from the rear of the PCB before soldering the connections. Once all the wires are in place, fit a cable tie around the four switch wires to prevent them from pulling away from the PCB. It's also a good idea to use neutral-cure silicone or hot melt glue to hold the wires in place.

The remote PCB can now be mounted on the base of the case. Both the Jaycar and Altronics remotes have two holes that can be used as mounting points, although the Jaycar unit's holes will need to be enlarged to 3mm. In each case, the unit can be mounted (copper side up) on 9mm tapped spacers and secured using M3 x 5mm machine screws.

Once it's in place, plug the various leads into the sockets on the back of the timer PCB and fasten the lid down. That's it – the unit is ready for use. The full instructions on driving it are in the accompanying panel. SC

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How to find faults in coaxial cables using TDR

TDR or time-domain reflectometry is a technique used to track down faults in cables – mainly coaxial cables but other types as well. But do you know how TDR actually works? This article is a primer on TDR. It's a lot easier to understand than you may think and we also explain what the terms "velocity factor" and "characteristic impedance" mean.

By JIM ROWE

DON'T BE PUT OFF by that complex sounding term "time-domain reflectometry" or its cryptic acronym "TDR". They're just techno jargon for a fault-finding technique that's simpler than it sounds – at least in principle.

First off, we need to explain that the main use for TDR is for finding faults and discontinuities in cables – primarily coaxial cables. These are the cables used to carry RF signals between antennas, receivers and transmitters and also to carry RF, video and high-speed digital signals between professional and domestic equipment.

In essence, coaxial cables behave as transmission lines, in that when electrical energy is fed into one end of the cable, it takes a finite time for that energy to travel along the cable to the other end. That's because the distributed inductance and capacitance inside the cable force the energy to propagate along it in the form of an electromagnetic wave (a combination of electric and magnetic energy).

This is very similar to light energy travelling along a fibre-optic cable – which is not surprising, because light is simply electromagnetic (EM) energy of a much higher frequency. When any kind of EM energy is propagating through empty space (ie, a vacuum), it does so at the speed of light, equal to 299,724,580 metres per second, or near enough to 300,000km/s.

By the way, this equates to 300 metres per microsecond (300m/μs) and also to 300 millimetres per nanosecond (300mm/ns). Both of these figures are worth remembering.

When EM energy is propagating through a more substantial medium like a coaxial cable (or a fibre-optic cable in the case of light), it moves at a slower speed; still very fast but not quite as fast as light in a vacuum.

Velocity factor

In the case of EM energy propagating along a coaxial cable or similar transmission line, its speed or velocity (V_p) is related to the speed of light in a vacuum by a factor known as the "velocity factor" (V_f) of the cable. In other words:

$$V_p = V_f . c \quad \ldots (1)$$

where c is the speed of light in a vacuum.

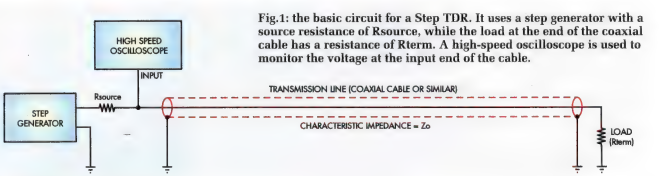


Fig.1: the basic circuit for a Step TDR. It uses a step generator with a source resistance of Rsource, while the load at the end of the coaxial cable has a resistance of Rterm. A high-speed oscilloscope is used to monitor the voltage at the input end of the cable.

As you might expect, the value of V_f is closely related to the dielectric constant E_r of the dielectric material used in the cable itself – between the centre conductor and the outer screen conductor. In fact:

$$V_f = 1/\sqrt{E_r} \quad \ldots (2)$$

Most commonly available coaxial cables use a polyethylene (PE) dielectric in either solid or cellular foam form – or as small discs of solid PE spaced apart ("air-spaced" PE). A small number of cables for specialised applications use dielectric materials like fluorinated ethylene propylene (FEP), poly tetrafluoroethylene (PTFE) or polyvinyl chloride (PVC).

Table 1 shows the dielectric constant E_r, the velocity factor V_f and the propagation velocity V_p of some common types of coaxial cable dielectric, along with the figures for air or a vacuum for comparison. This information comes in handy when you're using a TDR adaptor with a scope to locate the position of faults or discontinuities in cables.

Table 1: Common Coaxial Cable Dielectrics

DIELECTRIC MATERIAL	E_r (DIELECTRIC CONSTANT)	V_f (VELOCITY FACTOR)	V_P (VELOCITY OF PROPAGATION)
AIR (OR VACUUM)	1.00	1.00	300mm/ns
SOLID PE	2.3	0.66	198mm/ns
CELLULAR FOAM PE	1.4 – 2.1	~0.87	261mm/ns
AIR SPACED PE	~1.1	0.95	285mm/ns
SOLID PTFE	2.1	0.69	207mm/ns
CELLULAR FOAM PTFE	1.4	0.84	252mm/ns
SOLID FEP	2.1	0.69	207mm/ns
CELLULAR FOAM FEP	1.5	0.82	246mm/ns

Note: velocities shown in millimetres per nanosecond (10^{-9}s)

Characteristic impedance

Now let's consider another important aspect of coaxial cables and other transmission lines: their characteristic impedance. Just as the distributed capacitance and inductance of a cable forces EM energy to propagate along it at a specific velocity, they also force the energy to adopt a specific voltage-to-current ratio. This V/I ratio is called the cable's characteristic impedance, and is usually represented as "Zo".

The value of Zo for any particular cable depends mainly on the ratio of the outer conductor's inside diameter (D) to the inner conductor's outside diameter (d), together with the dielectric constant of the insulating material between them (E_r). In fact, if you neglect the series resistance of the inner and outer conductors per unit length, the Zo of a coaxial cable can be found from this simple formula:

$$Zo = (138\Omega/\sqrt{E_r}) \times \log(D/d) \quad \ldots (3)$$

which can be simplified to:

$$Zo = 138\Omega \times V_f \times \log(D/d) \quad \ldots (4)$$

Although you can calculate the Zo of any particular cable with this formula, it's generally not necessary because cable manufacturers usually provide this information. Table 2 shows the relevant details for some common coaxial cables. All of them have a Zo of either 50Ω or 75Ω.

Knowing the Zo of a cable is important because when the cable is used to transfer electrical energy from a source or "generator" to a load, you only get maximum power transfer when the generator's source resistance/impedance and the load's resistance/impedance are both matched to the Zo of the cable.

If the load resistance is not matched to the cable impedance (Zo), some of the energy reaching the load end of the cable is reflected back along the cable to the generator (with a polarity which may be the opposite of the 'incident' energy). If the source resistance of the generator is not matched to the cable Zo either, some of this returned energy is reflected back towards the load again. The net result is that some of the energy bounces back and forth along the cable and is wasted as heat.

So a cable's Zo or characteristic impedance is most important in that it allows you to match the resistance of the load and generator to it, in order to achieve the most efficient transfer of energy/power (and preserve signal integrity).

TDR basics

Having explained coaxial cable operation and the significance of V_p (velocity of propagation) and Zo (characteristic impedance), we are primed to understand the basics of TDR.

First, there are actually three versions of TDR, known as "Step TDR", "Pulse TDR" and "Spread-Spectrum TDR".

We're going to be dealing mainly with Step TDR because it's the version most commonly used nowadays and it's the easiest to understand.

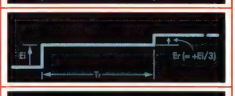
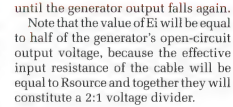
Now take a look at the simple circuit in Fig.1. It shows a length of coaxial cable connected between a voltage step generator and a load resistor. The step generator has a source resist-

Table 2: Typical Characteristics Of Some Common Coaxial Cables

CABLE TYPE	DIELECTRIC	V_P (VELOCITY OF PROPAGATION)	D/d (mm/mm)	Zo (CHARACTERISTIC IMPEDANCE)	Loss (dB/m @ F)	COMMON USES
RG-6/U	CELLULAR FOAM PE	261mm/ns	4.7/1.0	75Ω	0.2 @ 1GHz	CABLE TV & SATELLITE ANTENNA INSTALLATIONS
RG-58/U	SOLID PE	198mm/ns	2.9/0.81	50Ω	1.056 @ 2.4GHz	THIN ETHERNET, RF & INSTRUMENTATION
RG-59/U	SOLID PE	198mm/ns	3.7/0.64	75Ω	0.39 @ 1GHz	BASEBAND VIDEO, DOMESTIC TV ANTENNAS
RG-174/U	SOLID PE	198mm/ns	1.5/(7 x 0.16)	50Ω	2.46 @ 2.4GHz	WI-FI PIGTAILS, GPS & INSTRUMENTATION
RG-213/U	SOLID PE	198mm/ns	7.2/(7 x 0.75)	50Ω	0.27 @ 1GHz	LOW LOSS UHF ANTENNA CABLES

Note: RG-XX/U type numbers are a carry-over from US military specs during WW2. They are nowadays used mainly to identify matching connectors.

Table 3: Scope Displays With Step Generator

CONDITIONS	RESULT	OSCILLOSCOPE DISPLAY
Zo = Rsource Rterm = Zo (CORRECT MATCHING)	ALL ENERGY IS CARRIED TO THE LOAD, WITH NO REFLECTED ENERGY	
Zo = Rsource Rterm = ZERO (SHORT CIRCUIT AT LOAD END)	ALL ENERGY REFLECTED BACK TO THE GENERATOR, BUT WITH REVERSED POLARITY (Tr = 2 x cable transit time)	
Zo = Rsource Rterm = INFINITY (OPEN CIRCUIT AT LOAD END)	ALL ENERGY REFLECTED BACK TO THE GENERATOR, BUT WITH THE SAME POLARITY (Tr = 2 x cable transit time)	
Zo = Rsource Rterm = 2 x Zo (TWICE Zo & Rsource)	ENERGY REFLECTED BACK TO THE GENERATOR, BUT WITH THE SAME POLARITY (Tr = 2 x cable transit time)	
Zo = Rsource Rterm = Zo/2 (HALF Zo & Rsource)	ENERGY REFLECTED BACK TO THE GENERATOR, BUT WITH REVERSED POLARITY (Tr = 2 x cable transit time)	

ance of Rsource, while the load has a resistance of Rterm (shortened from Rterminating). The only other item in the circuit is a high-speed oscilloscope with its input being used to monitor the voltage at the input end of the cable.

To begin, consider the situation where both Rterm and Rsource are correctly matched to the Zo of the cable. What would you expect to see on the scope?

In this case, you would see a single voltage step as shown in the top trace of Table 3. The step would have an amplitude of Ei volts and would continue at that level indefinitely – or at least until the generator output falls again.

Note that the value of Ei will be equal to half of the generator's open-circuit output voltage, because the effective input resistance of the cable will be equal to Rsource and together they will constitute a 2:1 voltage divider.

Shorting the cable

Now consider what the scope would show if the load resistor Rterm were replaced with a short circuit – in effect, a resistor of zero ohms. This would be an extreme mismatch at the load end of the cable and as a result all of the voltage step energy would be reflected back towards the generator as another voltage step Er – with the same amplitude as Ei but of opposite polarity.

So the scope display would look like the second trace in Table 3, with the voltage at the cable input dropping to zero as soon as the reflected energy arrived back.

Note the significance of Tr. It is the time between the start of the voltage step and its sudden end. It represents the time taken for the incident step to travel to the end of the cable, plus the time taken for the reflected step to travel back to the start. In other words, it will be equal to twice the cable transit time. And we can work out the transit time. It's equal to:

$$T_{transit} = L/V_p \quad \ldots (5)$$

where V_p is the velocity of propagation in the cable (as before, measured in mm/ns), while L is the cable length in millimetres.

So Tr will equal twice this value and if we measure Tr using the scope we can calculate the effective length of the cable using this rearranged equation:

$$L = (Tr \times V_p)/2 \quad \ldots (6)$$

where L is the cable length in millimetres, Tr is the step "length" in nanoseconds and V_p is the velocity of propagation in mm/ns. So by measuring Tr, we can quite easily work out the cable length – or more precisely the distance to the short circuit.

Disconnecting the cable

Next consider what would happen if we removed the short circuit from the load end of the cable and left it without any termination at all – an open-circuit. This will again represent an extreme mismatch but of the opposite kind to a short circuit.

All of the voltage step energy will again be reflected back to the generator as a voltage step Er, but this time with the same polarity as Ei.

When the reflected step reaches the start of the cable, the scope will show the voltage suddenly rising to twice its initial value, as shown in the third trace of Table 3. The Tr time will still have the same significance as before, in this case allowing us to work out the cable length to the open circuit. Get the idea?

Now let's consider what would happen if we don't connect a short circuit or an open circuit to the end of the cable but instead connect a load

Scheduled for publication in the December issue, this do-it-yourself adaptor lets you use any reasonably "fast" scope to perform step TDR on your own cables.

resistor with a value Rterm which is TWICE the value of Zo and Rsource. This is again a mismatch, although not as severe as a short or open circuit. Some of the voltage step energy will be reflected back towards the generator but not as much as before – and with the same polarity as Ei.

So the scope will show an upward step after time Tr, with a step height Er in this case equal to Ei/3 as shown in the fourth trace of Table 3.

Voltage reflection coefficient

Perhaps you're wondering why the value of Er is only equal to a third of Ei, when the load resistance is twice the value of Zo? That's because Er and Ei are related by a factor called the voltage reflection coefficient (Rho), which has a value given by this expression:

Er/Ei = Rho = (Zload - Zo)/(Zload + Zo) ...(7)

where Zload is the load impedance, which in this case is equal to 2Zo. Rearranging this and substituting for Zload, we find that the value of Er becomes:

Er = Ei(2Zo - Zo)/(2Zo + Zo)
= Ei.Zo/3Zo = Ei/3 . . . (8)

Next consider what will happen if we again connect a load resistor to the end of the cable but this time with a value which is HALF the value of Zo and Rsource. Again this is a mismatch, so some of the voltage step energy will be reflected back towards the generator as before. This time though, the reflected voltage Er will be reversed in polarity compared with Ei, because the load resistance is lower than Zo.

You can see the resulting downward step in the fifth (lowest) trace in Table 3. You'll also see that the value of Er is again equal to one third of Ei, which is confirmed thus:

Er = Ei(Zo/2 - Zo)/(Zo/2 + Zo)
= Ei(-Zo/2)/(3Zo/2) = -Ei/3 . . . (9)

From these five examples you'll be starting to see how TDR works and how it allows us to calculate some important details about the operation of a cable and transmission line:

(1) Whether the cable is correctly terminated in a matched load, which means no reflected energy. This is shown by the voltage step extending indefinitely.

(2) If there is a further step in the scope display, indicating some kind of mismatch, then the Tr time between the initial step and the "reflection" step can be used to work out the length of cable L between the generator end and the mismatch.

(3) The amplitude and polarity of the reflected voltage step Er can be used to work out the effective resistance of the mismatched load.

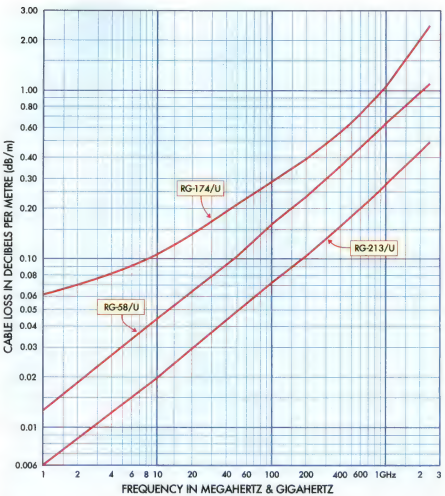


Fig.2: these curves show the losses in three common types of 50Ω coaxial cable as a function of frequency. RG-174/U cable ranges from 0.06dB/m at 1MHz up to almost 2.5dB/m at 2.4GHz, while RG-213/U cable ranges from just 0.006dB/m at 1MHz up to 0.49dB/m at 2.4GHz. RG-58/U cable is midway between these two.

Cable losses

There's one complication we need to consider before moving on: the effect of cable losses.

In the discussion so far, we've made the assumption that the cables being tested are "perfect", in the sense that when the generator and load resistances are properly matched to the cable's Zo, all of the energy fed into the cable at one end emerges from the other end and passes into the load. In other words, we've assumed that the cables are lossless.

But in the real world, nothing is perfect. As shown in column six in Table 2, all cables have a loss which is usually listed in terms of decibels per metre (dB/m), or decibels per 100 feet (dB/100ft) in countries like the USA which still use the Imperial system.

Because cable losses rise with increasing frequency, the loss figure is usually qualified with a frequency figure, as shown.

To put things into perspective, look at the curves in Fig.2. These show the losses in three common types of 50Ω coaxial cable, all plotted against frequency.

As you can see, the small diameter RG-174/U cable has a loss figure ranging from 0.06dB/m at 1MHz up to almost 2.5dB/m at 2.4GHz, while RG-213/U cable with its much larger diameter has a loss figure ranging from only 0.006dB/m at 1MHz up to 0.49dB/m at 2.4GHz.

The common RG-58/U cable is midway between the other two in terms of its loss factor – ranging from

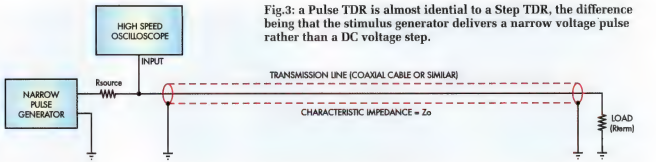


Fig.3: a Pulse TDR is almost idential to a Step TDR, the difference being that the stimulus generator delivers a narrow voltage pulse rather than a DC voltage step.

0.013dB/m at 1MHz up to just over 1.00dB/m at 2.4GHz.

So real cables do lose some of the input EM energy (as heat), even when the generator and load are correctly matched to their Zo. But what effect does this have when you are checking a cable using Step TDR?

This depends on things like the cable loss factor and the cable's length. These are not likely to have much effect on a fairly short cable but when you're checking a fairly long run of a relatively lossy cable, the cable loss will tend to attenuate the indicated level of reflected step Er. So any mismatch will appear to be less serious than it should.

Pulse TDR

Remember that the version of TDR we've been discussing so far is Step TDR – the name referring to the way it uses a voltage step waveform as the incident "stimulus" being fed into the cable to be tested. But we're now going to look briefly at the other basic version: Pulse TDR, where a short voltage pulse is used as the stimulus rather than a step.

Fig.3 shows the basic circuit for a Pulse TDR. It's almost identical to the Step TDR circuit of Fig.1, the only difference being that the stimulus generator is now labelled 'Narrow Pulse Generator'; it generates a narrow voltage pulse rather than a step.

In effect, Pulse TDR works in much the same way as Step TDR. If you compare the traces shown in Table 4 with those for Step TDR in Table 3, you'll see that the only differences are that each voltage step of Table 3 is now replaced with a voltage pulse. The basic behaviour is unchanged, because we're still looking at the effects caused by the interaction between cable parameters Vp and Zo and changes in load resistance.

Table 4: Scope Displays With Pulse Generator

CONDITIONS	RESULT	OSCILLOSCOPE DISPLAY
Zo = Rsource Rterm = Zo (CORRECT MATCHING)	ALL ENERGY IS CARRIED TO THE LOAD, WITH NO REFLECTED ENERGY	
Zo = Rsource Rterm = ZERO (SHORT CIRCUIT AT LOAD END)	ALL ENERGY REFLECTED BACK TO THE GENERATOR, BUT WITH REVERSED POLARITY (Tr = 2 x cable transit time)	
Zo = Rsource Rterm = INFINITY (OPEN CIRCUIT AT LOAD END)	ALL ENERGY REFLECTED BACK TO THE GENERATOR, BUT WITH THE SAME POLARITY (Tr = 2 x cable transit time)	
Zo = Rsource Rterm = 2 x Zo (TWICE Zo & Rsource)	ENERGY REFLECTED BACK TO THE GENERATOR, BUT WITH THE SAME POLARITY (Tr = 2 x cable transit time)	
Zo = Rsource Rterm = Zo/2 (HALF Zo & Rsource)	ENERGY REFLECTED BACK TO THE GENERATOR, BUT WITH REVERSED POLARITY (Tr = 2 x cable transit time)	

Step TDR is more popular

But if there's so little difference between the two, why is Step TDR more popular than Pulse TDR? For a couple of reasons, one being that during the stimulus pulse in Pulse TDR, the scope can't be allowed to monitor the cable input voltage Ei because it would be overloaded. So with this approach, the stimulus pulse creates a 'dead zone', during which the scope can't look for reflections.

But when the pulse width is made very narrow to reduce the dead zone, this also reduces the TDR's range. So Pulse TDRs generally need to provide a number of different pulse widths, to achieve different trade-offs between dead zone and range.

Another allied problem with Pulse TDRs is that because a pulse stimulus carries much less energy than the step stimulus, the technique is not capable of delivering the same signal to noise ratio. So with real-world (read "lossy") cables, Pulse TDR can't reveal cable faults or discontinuities as clearly as Step TDR.

Summarising

You should now have a reasonable understanding of what TDR is, how it works and how it's used for checking coaxial cables in particular. Think of it as "echo location for cable faults" if you like.

And as you may have guessed, this article is a prelude for a planned low-cost adaptor which lets you use any reasonably "fast" scope to perform Step TDR on your own cables. Look for it in the December issue. SC

What's the State-Of-Play with Electric Vehicles

by Ross Tester

Despite a relatively slow uptake by the market, a recent report suggests that's all about to change. The 197-page, $US4000 '*Electric Vehicle Forecasts, Trends and Opportunities 2015-2025*' report by UK research group IDTechEx claims that world-wide pure electrics and hybrids sales are expected to exceed half a trillion dollars by 2025.

The electric vehicle market here in Australia has been patchy, to say the least. The Toyota Prius (hybrid) has been far and away the most popular but other entrants into the hybrid market, such as the Holden Volt, have found it a much tougher market to crack.

Pure electrics, such as the Mitsubishi iMiEV (see SILICON CHIP February 2011) and Nissan LEAF (SILICON CHIP, August 2012) have had an even more difficult history. Mitsubishi was reported to have ceased importing the iMiEV back in 2013 (though that's not certain!), while Nissan has still been selling discounted 2012-build LEAFs this year in Australia, despite the 2014 model being released overseas.

Indeed, the latest figures we've seen said that of the 266,370 vehicles sold in Australia last year, only 42 were electrics.

Perhaps they will be given a 'jump start' with the impending release of two heavyweights here in Australia . . .

Tesla

Tesla Motors, with their (very) up-market – and up-price – range of pure electrics, are preparing to open showrooms in Sydney and Melbourne 'before the end of the year'. We're not sure where they will be getting their stock from, however: Tesla has closed its order books in the USA for the time being as they simply cannot keep up with demand.

Tesla has earned an enviable reputation for developing outstanding vehicles. Its luxury Model S also achieves a perfect 5.0 NHTSA safety rating but at an expected price of about $AU100,000 it won't be the car for everyone!

BMW

BMW's $64,000 all-electric i3, announced earlier this year, was reported as being available 'around the end of the year' (ie, about now! So far, we haven't seen any ramp-up in advertising, which we would have expected for an imminent release. BMW are promoting this as a 'premium vehicle' to fit in with their 'premium brand'; hence the 'premium price'.

The main problem with pure electric vehicles (and even hybrids to some extent) is price. The iMiEV was the cheapest of the lot and it sold for more than $30,000 – for a vehicle which compared with several other sub-compacts in the $15-$20,000 range.

The LEAF didn't fare much better – even with a $39,990 price tag (much better than the original $54,000+) it too has not proved a marketing show-stopper.

Perhaps marketing is the key – with limited range all-electrics (the LEAF is supposed to be good for 170km but experience suggests 130-150 is closer to the mark) they cannot be marketed as a family car. However, they are the perfect "second" car; none better for commuting to work, running down to the shops, taking the kids to sport on weekends and so on.

With dramatically lower ongoing costs (both 'fuel' and maintenance) they make the normal family car seem incredibly hungry. But if you want to go away for holidays etc, you need to either take that normal car or as many people do now, fly (at heavily discounted prices) and hire a car when you get there.

Hybrids

We mentioned hybrids earlier and the IDTechEx report states that sales for these are rapidly growing worldwide, at the expense of conventional cars. Mitsubishi's PHEV Outlander is but one example released here recently – again, though, it is at a significant premium to the ICE-only varieties.

New models

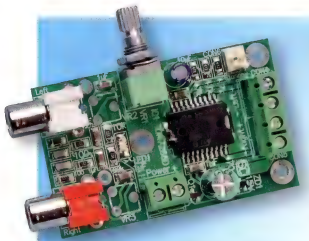
Over the years, there have been literally dozens of announcements from car companies, both large and unknown, that they are planning on introducing an electric car 'shortly'. With few exceptions (Tesla and BMW included!) these cars either disappear or are still a twinkle in a developer's eye.

Once again, though, that could be changing. The IDTechEx report states that Foxconn (a company which makes Apple equipment) has recently partnered with another Chinese manufacturer, BAIC Motor Corp, to produce a sub-$15,000 pure electric car. It also reports that General Motors is well down the path of releasing a $30,000 pure electric and also achieving one of the 'holy grails' of electric vehicles, a model with 200 mile (320km) range per charge.

Tesla, too, is putting a lot of effort into new battery technology (a significant proportion of electric vehicle cost), aiming to produce a battery for $100 per kWh within the decade. That could translate to even higher range. (See **www.idtechex.com/ev**). SC

Tesla Model S

BMW i3



One-Chip Mini 2 x 5W Stereo Amplifier

It doesn't get much simpler than this. With one IC and not much else, you get a stereo 5W amplifier that can operate over a wide range of voltages, from 3.5V to 15V. That means it can run off a single or multiple Li-Po cells, USB power or a lead-acid battery. It's a small and inexpensive module that can do a range of audio amplification jobs.

By NICHOLAS VINEN

OUR VARIOUS "chimp amplifier" or "champ" projects have been very popular because they're easy to build and in many cases, are all you need to drive a small (or possibly even large) speaker. The Champion (SILICON CHIP, January 2013) was no exception. Unfortunately, the AN7511 IC we used in that project has been discontinued by Panasonic and has become difficult to obtain.

The TDA7266D used in this little module is one of the most common small Class-B audio amplifier ICs available today and is made by ST Microelectronics. While there is a through-hole version, the SMD package variant is easier to get and smaller too.

It has large pins so it isn't too difficult to solder; the only tricky part is the large thermal pad as this can suck away quite a bit of heat while soldering. That does mean it's fairly effective at taking away heat during operation though, so for most applications, the PCB makes a quite adequate heatsink.

This single package provides a stereo bridge-tied load (BTL) amplifier, which is ideal for getting maximum Class-B power into a pair of speakers. For example, it will deliver nearly 1W per channel into 8Ω speakers with a supply of just 4V, as is typically available from a single Li-Ion or Li-Po cell. Its performance is pretty respectable too, as you can see from the specs and performance graphs.

This IC also has over-temperature protection, output short circuit protection and shut-down/mute functions. We've added RCA socket inputs, a volume control and supply reverse polarity protection to complete the package.

In comparison to the Mini-D switching amplifier from the September 2014 issue, this amplifier is smaller, simpler and costs less to build. It can also run off lower supply voltages. Of course, the Mini-D does offer substantially more power with higher efficiency and can run off higher voltage supplies. It's basically a case of "horses for courses"; build the one that best suits your requirements.

Circuit description

The full circuit is shown in Fig.1. The input signal for each channel, from RCA sockets CON1 & CON2, passes through low-pass filters comprising 100Ω series resistors and 1nF ceramic capacitors to ground. These filters reduce audible hash and noise which may be picked up by the input leads. 10Ω resistors in series with each input ground improve channel isolation.

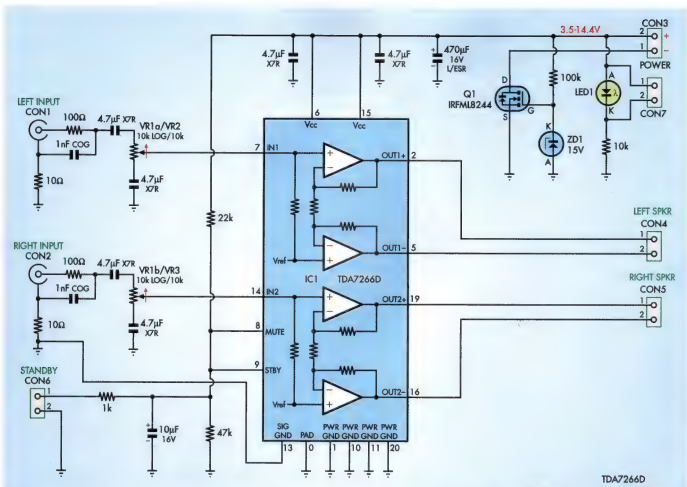
The audio signals are then AC-coupled to the 10kΩ volume control potentiometer(s) with 4.7µF ceramic capacitors, giving a -3dB bass roll-off point around 7Hz. You can either use two trimpots (VR2/VR3) for preset volume or a dual log pot (VR1) for adjustable volume.

The bottom end of each pot is AC-coupled to ground to prevent DC current passing through the pots, which would cause audible crackling during volume adjustment. The signals then go straight into IC1's input pins, pin 7 for the left channel and pin 14 for the right channel. An internal half-supply bias voltage provides the correct DC levels.

The internal negative feedback sets the gain to 26dB (20 times).

The output signals go straight to terminal blocks CON4 and CON5. The outputs are bridge-tied so neither speaker has a ground connection. In other words, both ends of each speaker is actively driven with anti-phase signals, for maximum power delivery.

The components connected to pin 8 (mute) and pin 9 (standby) prevent clicks and pops at power-up. When power is applied, both pins are held low so the outputs are off. Over time, the 10µF capacitor charges and IC1 first comes out of standby mode and



ONE-CHIP MINI STEREO AMPLIFIER

Fig.1: the circuit of the One-Chip Mini Stereo Amplifier. It's based on TDA7266D amplifier chip and can deliver in excess of 5W per channel. VR1 is the volume control, while Mosfet Q1 provides supply reverse polarity protection.

into active mode, and then once other voltages have stabilised, the outputs are un-muted.

If the two pins of CON6 are shorted, eg, by a switch, or if pin 1 is pulled low, the 10µF capacitor will discharge and the unit will mute its outputs and then go into standby mode. In standby mode, the quiescent current drops to a low level. If this short is then removed, the unit powers back up and operates as normal.

So CON6 can thus be used to save power when the amplifier isn't being used and it may be under control of a microcontroller. If you don't need this feature, you can leave the connector off and the amplifier will simply operate whenever power is available.

Each power supply pin of IC1 (pins 6 & 15) has an adjacent 4.7µF ceramic bypass capacitor plus there is a 470µF electrolytic reservoir capacitor. LED1

Features & Specifications

- **Supply voltage:** 3.5-15V
- **Quiescent current:** 40-60mA
- **Standby current:** ~0.25mA
- **Load impedance:** 4Ω or higher (see Table 1)
- **Output power:** in excess of 5W per channel, thermally limited
- **Gain:** adjustable, up to 26dB (20x)
- **Signal-to-noise ratio:** ~96dB
- **Channel separation:** ~66dB
- **Input impedance:** 10kΩ
- **Power supply rejection ratio:** ~56dB
- **THD+N, 2 x 1W:** typically 0.03% @ 1kHz, <0.1% 100Hz-5kHz (see Figs.2 & 5)
- **Frequency response:** 20Hz-20kHz, ±1dB, typically ±0.1dB (see Flg.3)
- **Other features:** power indicator LED, standby, short circuit protection, over-temperature shut-down
- **Standby muting:** 110dB

Parts List

1 double-sided through-plated PCB, code 01109141, 39 x 63.5mm
2 switched right-angle PCB-mount RCA sockets, white & red (CON1,CON2) OR
2 2-way pin headers or polarised headers, 2.54mm pitch (CON1,CON2)
3 2-way mini terminal blocks, 5.08mm pitch (CON3-CON5)
1 10kΩ 9mm dual gang PCB-mount log pot (VR1) OR
2 10kΩ mini horizontal trimpots (VR2,VR3)
1 2-pin polarised header (optional, for standby function)
6 M3 x 6mm machine screws (for mounting)
3 M3 tapped Nylon spacers (for mounting)

Semiconductors

1 TDA7266D 2x5W amplifier IC, PowerSO-20 (IC1)
1 IRFML8244 N-channel Mosfet or equivalent, SOT-23 (Q1) (element14 1857298)
1 15V 500mW zener diode, SOT-23 (ZD1) (eg, BZX84-C15; element14 1826097)
1 high-brightness SMD LED, size 3216/1206* (eg, element14 2290350) OR
1 2-way pin header, 2.54mm pitch plus off-board high-brightness LED

Capacitors (SMD 3216/1206* ceramic unless stated)

1 470µF 16V low-ESR electrolytic
1 10µF 16V electrolytic
6 4.7µF 25V X7R (element14 1828835)
2 1nF 50V X7R or C0G/NP0 (element14 1414658)

Resistors (SMD 3216/1206*, 1/8W, 1%)

1 100kΩ (element14 9241060)
1 47kΩ (element14 9336583)
1 22kΩ (element14 9241027)
1 10kΩ (element14 513222)
1 1kΩ (element14 9240942)
2 100Ω (element14 1632521)
2 10Ω (element14 9335790)
* 2012/0805 size also suitable

(or an external LED connected to CON7) lights to indicate when power is applied.

Mosfet Q1 provides reverse polarity protection. The supply voltage is fed in via CON3 and if the polarity is correct, Q1's gate is pulled up via the 100kΩ resistor, switching it on and making the connection between IC1's ground and pin 1 of CON3. 15V zener diode ZD1 protects Q1's gate from high-voltage supply spikes.

If the supply is connected the wrong way around though, Q1's gate is pulled below its source and thus Q1 is off and no supply current can flow. Again, ZD1 protects Q1's gate from going too far negative.

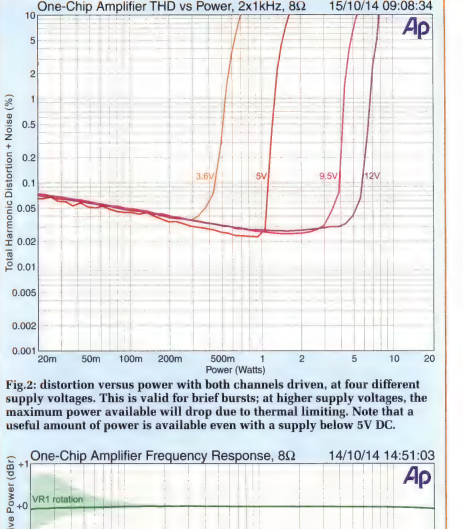


Fig.2: distortion versus power with both channels driven, at four different supply voltages. This is valid for brief bursts; at higher supply voltages, the maximum power available will drop due to thermal limiting. Note that a useful amount of power is available even with a supply below 5V DC.

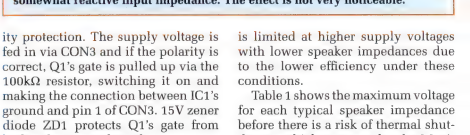


Fig.3: the frequency response is very flat above 100Hz. Below that, there is a small amount of bass cut or boost depending on the position of the volume pot(s). This is due to their varying source impedance interacting with IC1's somewhat reactive input impedance. The effect is not very noticeable.

Speaker load & power

The Mini Stereo Amplifier can drive speakers of 4-16Ω. However, power is limited at higher supply voltages with lower speaker impedances due to the lower efficiency under these conditions.

Table 1 shows the maximum voltage for each typical speaker impedance before there is a risk of thermal shutdown at higher power levels. Maximum contiuous power is available at the upper voltage specified, ie, best power into 8Ω is available at around 9.5V. Under these conditions, it will deliver 2 x 5W at 10% THD+N or 2 x 4W at 1% THD+N.

Note that there is nothing stopping you from running the unit from a higher voltage than shown in Table 1 but if you drive it hard, it could over-

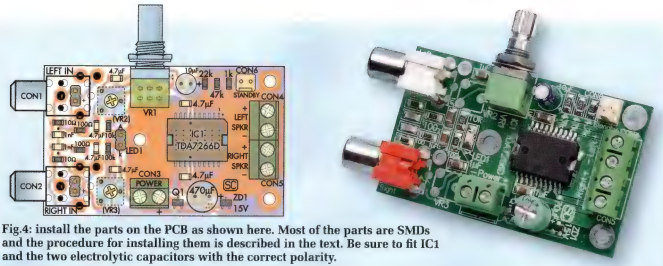


Fig.4: install the parts on the PCB as shown here. Most of the parts are SMDs and the procedure for installing them is described in the text. Be sure to fit IC1 and the two electrolytic capacitors with the correct polarity.

Table 1

Load Impedance	Supply Voltage
4Ω	3.6-6.5V
6Ω	3.6-8.5V
8Ω	4-9.5V
16Ω	6-14V

heat and shut down briefly. Normal operation will resume once the chip has cooled. The IC can typically dissipate 5W total before its die reaches 150°C and it shuts down.

Construction

The amplifier is built on a double-sided PCB coded 01109141 (39 x 63.5mm). Most of the components are SMDs but there are a few through-hole parts involved too. Fig.4 shows the assembly details.

Start by fitting IC1, the amplifier chip. Because it's relatively large and the board is its heatsink, you will need a relatively powerful (and/or hot) iron to do this. The simplest technique involves little more than a typical soldering iron and some flux paste.

First, tin the large mounting pad on the PCB with a thin layer of solder. Spreading a little flux paste on this pad before adding solder will help spread it out. Keep the solder thin and even; if you add too much, remove the excess using some solder wick (again, flux paste helps).

Once you're happy with that, tin the underside of the IC in the same manner. You may need to hold it in some sort of clamp or vice while doing so. Then spread a little flux paste on the tinned PCB pad and place the IC on top, ensuring that its orientation is correct, ie, the notched corner (pin 1) is in the upper-right corner, near the dot on the PCB overlay. Push it down to make sure it's in intimate contact with the board.

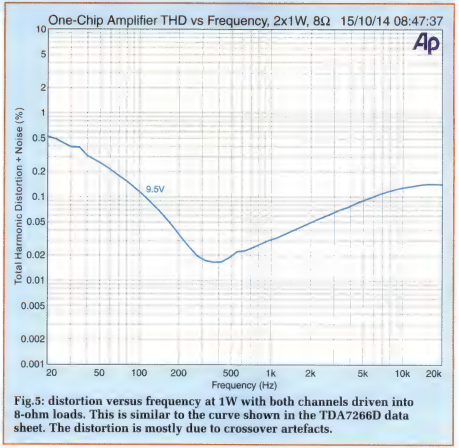


Fig.5: distortion versus frequency at 1W with both channels driven into 8-ohm loads. This is similar to the curve shown in the TDA7266D data sheet. The distortion is mostly due to crossover artefacts.

Line the IC up with its pads, place a dab of flux paste on one of the pins, then put a little solder on the tip of your soldering iron and touch the pin gently, without disturbing the IC. The flux paste should help "suck" the solder onto that pin and pad. Check the IC alignment and if necessary, reheat the joint and gently nudge it into place. Once the alignment is good, use the same technique to solder the diagonally opposite pin.

It's then simply a matter of heating the main tab under the IC until the two layers of solder melt and solidify into a single mass. Make sure the board is on a heat-resistant surface, then place the soldering iron tip on one of the exposed pads at either end of the IC and melt some solder wire in, to "wet" the joint and help transfer heat. Hold the iron in place until you see a puff of vapour from the liquefying flux under the IC and the solder at the opposite end of the thermal pad re-flows.

Note that this procedure could take

continued on page 101

The Digital Dividend, TV Channel Restack... and what it means to the Television Viewer

By Alan Hughes With Geoff Graham

As most Australian and New Zealand readers know, there has been a huge shift in the television landscape with the move to digital and the subsequent closure of the analog service. You may think that the disruption is over . . . but think again! There is more to come – and it has the potential to severely impact TV viewers around Australia and New Zealand.

With the closure of the analog TV service in Australia and the "digital restack" most of the TV channels numbered 52 to 69 (695-820MHz) have become unoccupied.

And as we saw in September 2014 SILICON CHIP, there are many thousands of low-power audio devices, mainly wireless microphones, which also currently use this band and will have to vacate by January 1 2015.

As a result of the restack, the Commonwealth Government agency ACMA was able to sell this spectrum (plus 140MHz in the 2.5GHz band) for almost $2 billion, which represented a significant windfall to the government. In fact, the Government refers to this as the "digital dividend".

The intended use for this spectrum is mobile broadband using 4G/LTE technology in the new 700MHz band. This should not be confused with the existing 4G service in the 2.5GHz band.

Australia is not alone in reaping benefits from the move to digital – the New Zealand Government sold a similar spectrum for $NZ270 million to TelecomNZ, Vodaphone and 2degrees.

The restack

Mobile broadband and TV services cannot easily share the same portion of a spectrum as the risk of mutual interference is too high.

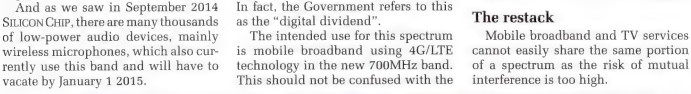


Fig.1: this is the Australian 4G/LTE frequency allocation – it shows where your old television frequencies have been reallocated to. The winners here are the growing mobile data services.

BLOCK A Band 3 (VHF high)	BLOCK B Band 4 (UHF)	BLOCK C Band 4 (UHF)	BLOCK D Band 5 (UHF)	BLOCK E Band 5 (UHF)
Channel 6	Channel 28	Channel 34	Channel 40	Channel 46
Channel 7	Channel 29	Channel 35	Channel 41	Channel 47
Channel 8	Channel 30	Channel 36	Channel 42	Channel 48
Channel 10	Channel 31	Channel 37	Channel 43	Channel 49
Channel 11	Channel 32	Channel 38	Channel 44	Channel 50
Channel 12	Channel 33	Channel 39	Channel 45	Channel 51
Frequency range(s) used on a specific transmitter site				
174-195MHz* & 209-230MHz*	526-568MHz	568-610MHz	610-652MHz	652-694MHz

*195-209MHz ("Channel 9 & 9A") reserved for DAB+ Digital Radio (capital cities at present)

Fig.2: in the restack, Australian RF channels are regrouped into similar frequencies sharing the one tower. In addition all transmitting antennas on an individual site will have the same polarisation, either horizontal or vertical.

As a consequence the Commonwealth Government committed $170 million (including advertising) to restack 1500 transmitters in 440 sites, with the restack scheduled for completion by the end of this year.

When the analog TV spectrum was laid out many years ago provision was made for a vacant analog channel to be placed either side of a transmitter channel in any one viewing area to prevent mutual interference.

Fortunately this is not required for digital TV, which is one of the reasons why digital is more efficient in its use of the spectrum.

The restack has allocated all transmissions for a given coverage area to a sequential block of channels. The advantages of this are simpler receiving antenna design, with improved performance.

On any one site, the transmitter for each of the five networks is allocated an RF channel from one of the blocks listed in Fig.2 and a 6th channel (a spare) is left unallocated.

Note that there are some exceptions – eg, NSW Central Coast & Queensland Gold Coast. They are exceptions because they have nine channel allocations and eight active transmitters on each site, because of overlapping licence areas. The other exception is community TV.

However, the Minister for Communications recently announced (on September 10) that Community Television, currently located in mainland state capitals using Block B, would cease transmission as free-to-air services on December 31, 2015 and become solely internet-based.

At the time of writing, the various community TV stations were lobbying heavily to have this decision overturned so they could remain on air, using the spare channel which the Minister maintains is necessary for "testing".

Radio frequency channels vs logical channel numbers

In the above discussion the channels referred to are radio frequency transmission channels, not the "TV channels" or "logical channel number" which are what the user selects.

When a digital TV or set-top-box is being set up it will search through the radio frequency transmission channels starting from RF channel 6. When a signal is received, the logical channel numbers (or "TV channel numbers") will be stored as labels associated with the radio frequency channel on which they were found.

These logical channel numbers (LCN) are transmitted along with the electronic program guide and the actual program material.

It is the LCN that the viewer selects to view a program. This means that the viewer selects programs by a network number and not the frequency used by the TV tuner.

As an example, in Perth the ABC transmits the same four programs on RF channels 12, 29, 41, 47 and 49. However all viewers select programs based on logical channel numbers of 2, 21, 22, 23, etc regardless of the RF channel being used.

New Zealand uses European RF channel numbers, so be careful when comparing them to Australian channel numbers.

A similar restack has been used in Europe with blocks of eight RF channels, of which two cannot be used because of potential interference. As part of their restack Europe is selling European channels 57 – 64. In New Zealand most free to air transmitters are on either European channels 32, 34, 36 or 33, 35, 37 with all antennas on any one site using the same polarisation.

4G/LTE – and what it means to you

Earlier we mentioned that the broadband mobile service will use the newly-vacated TV channels (and 2.5GHz bands) for providing 4G or LTE (Long-Term Evolution) mobile broadband services to devices like tablets and mobile phones. These are marketing names being used by the wireless broadband companies.

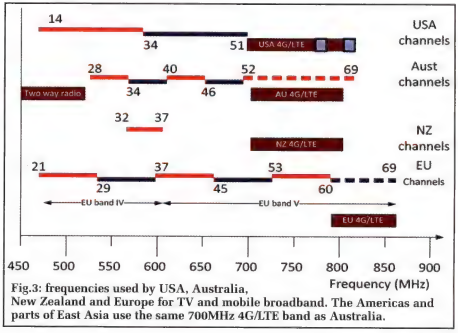
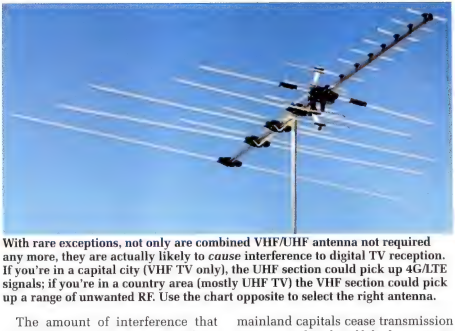


Fig.3: frequencies used by USA, Australia, New Zealand and Europe for TV and mobile broadband. The Americas and parts of East Asia use the same 700MHz 4G/LTE band as Australia.



With rare exceptions, not only are combined VHF/UHF antenna not required any more, they are actually likely to *cause* interference to digital TV reception. If you're in a capital city (VHF TV only), the UHF section could pick up 4G/LTE signals; if you're in a country area (mostly UHF TV) the VHF section could pick up a range of unwanted RF. Use the chart opposite to select the right antenna.

The amount of interference that may be generated between 4G/LTE transmitters and normal TV receivers is determined by the design of the equipment including the TV antenna, cabling and the receiver.

Another factor is the width of the guard band provided by ACMA. This band, at 698.5MHz, separates TV services using frequencies below 694MHz from 4G/LTE using frequencies above 703MHz (inclusive). New Zealand has a similar cut-off frequency.

Many TV antennas currently on the Australian market are designed to receive RF channels 52-69 along with other channels. This includes old VHF/UHF antennas and some new band three/UHF "digital" antennas as well as some UHF-only antennas.

As a result they will be sensitive to the 4G/LTE transmissions and could therefore make the interference created by this service even worse.

Tests have been done to assess the interference to 4G/LTE service by TV transmitters. However no known tests have been done to assess the interference to TV by 4G/LTE!

Interference can happen if the TV antenna is close to the device using 4G/LTE or if a mobile phone tower is between the TV antenna and the TV transmitter. The effect is that whenever the tablet or the mobile phone transmits, the TV reception can break up or freeze – and/or the sound can be disrupted.

VHF/UHF transmissions to cease nationally

Once Community TV stations in mainland capitals cease transmission on UHF, only a handful of areas *may* need a VHF/UHF antenna – a few areas where both bands will continue to be used. Therefore, a much cheaper Band-3-only (VHF) design will suffice and should suffer no (or minimal) interference from 4G/LTE.

Caveat Emptor – let the buyer beware

The first issue for consumers is that imported antennas are often designed for Europe and even the newer designs labelled "LTE" provide no protection from Australian or New Zealand wireless broadband. Also, these antennas often contain a 790MHz low pass filter, which is not much use in Australia/NZ.

A second issue is that most of the antennas available from Australian manufacturers are designed to receive up to channel 69 which makes them sensitive to 4G/LTE transmissions.

The final issue is that masthead and wideband distribution amplifiers are particularly susceptible to interference from 4G/LTE signals, so they need to contain a 698MHz low-pass filter to remove these signals.

For example, the Kingray Edge series and Johansson 4GP series of masthead amplifiers contain the necessary filters.

Reducing interference

So, what can you do? For a start the TV antenna that you are using should be designed to receive only the channels of the transmitter site for your viewing area. This will maximise the TV signal and minimise interference.

This particularly applies to weak signal areas using RF channel 51 such as Newcastle, Illawarra, SW Slopes/E. Riverina NSW, Southern Downs Qld, Murray Valley, Nhill, Geelong Vic, NE Tasmania. Low-powered translators using channel 51 in 154 towns and suburbs around Australia are also susceptible.

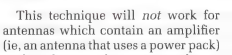
To determine the RF channels used in your area you should go to **http://myswitch.digitalready.gov.au/** and enter your street address. Click on 'Channels for…' and scroll down to 'Technical information for…' The RF transmission channels that your antenna will be required to receive will be shown there.

The panel opposite titled "Suitable TV Antenna Designs" will then provide you with details of the antenna suited to your location.

If a masthead amplifier is required it should not amplify signals outside the range of band 3 (174-230MHz) and UHF (526-694MHz).

For New Zealande readers the range is the European channels 26-47 (510-686MHz).

Existing installations which are suffering from interference and do not contain an amplifier can be improved by inserting a filter at the input to the receiver as illustrated below. This low pass filter will reduce the 4G/LTE signal to just 1/316 of its original power (-25 dB).



This technique will *not* work for antennas which contain an amplifier (ie, an antenna that uses a power pack) such as those used on caravans, boats, flat outside and indoor antennas.

This is because the filter must precede any amplification. As a further issue the locations used by these antennas often have mobile broadband devices close to the antenna.

People who receive their signal via a Master Antenna Television system (usually large apartment blocks, hotels etc) will require a qualified antenna installer to locate and rectify any issues.

Finally, a corroded antenna is a potent source of trouble, so any old antenna should be replaced as a matter of course.

Antenna installers

You need to be careful when accepting the advice of an antenna installer.

They may not have kept up with recent changes and you could end up with an inappropriate antenna based on what they have used in the past.

For example, there are *still* people installing the large and expensive antennas required for analog channel 2 – despite the fact that the last channel 2 signal was switched off in December 2013!

Antenna installers are not required to have any training in antenna selection and unfortunately the endorsement scheme used in Australia has been dismantled by the Department of Communications.

There is a new version of the Australian Standard AS1417-2014 Receiving Antennas for Radio and Television in the VHF and UHF band due to be published soon but there is no compulsion for the industry to use it.

As a consequence you are on your own when selecting a qualified installer.

Antenna suppliers

Antenna manufacturers and importers also have an important role to play. They need to supply the industry with antennas designed for the unique technical characteristics of the Australian and New Zealand market. This will reduce the chance of an installer using an inappropriate antenna.

This means that suppliers should:

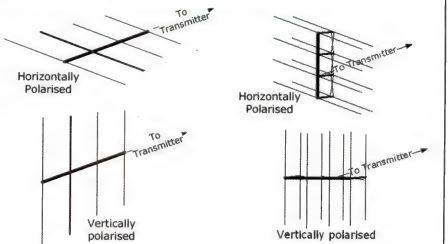
- **Not sell antennas** designed to receive any channel lower than channel 6 or higher than channel 51 (European channel 48).
- **Discontinue VHF/UHF combination** antennas or cross polarised antennas (by the end of this year all transmitters on a site will have the same polarisation).
- **Not sell UHF log periodic antennas.** Most of these are not required because of their wide frequency range and lack of sensitivity.

As a minimum, any antenna designed for block E should contain a 698MHz low pass filter in the balun box.

Marine and caravan antennas as well as amplified indoor antennas need to have 174-230 and 526-694MHz filters installed internally between the antenna and the amplifier.

Existing broadband antennas typically quoted as being able to receiving channels 0-69 will produce unreliable reception and could cost much more than the right antenna for your area.

SUITABLE TV ANTENNA DESIGNS



Yagi Antennas **Phased Array Antennas**

These diagrams will help you identify the various types of TV antenna discussed in the article. The difference between the antennas for a particular polarisation is the element length and spacing which in turn is determined by the frequency or channel number

STRONG SIGNAL AREA: Dark Green on http://myswitch.digitalready.gov.au/

	Block A	Block B	Block C	Block D	Block E
Total Dipole length (mm)	740	273	254	237	222
Gain (dbi)	7	10	10	11	11
Horizontal Polarisation	Yagi	Yagi	Yagi	Yagi	Yagi
Vertical Polarisation	Phased Array	Phased Array	Phased Array	Phased Array	Phased Array

MEDIUM SIGNAL AREA: Light Green on http://myswitch.digitalready.gov.au/

	Block A	Block B	Block C	Block D	Block E
Total Dipole length (mm)	740	273	254	237	222
Gain (dbi)	8	11	11	12	12
Horizontal Polarisation	Yagi	Yagi	Yagi	Yagi	Yagi
Vertical Polarisation	Phased Array	Phased Array	Phased Array	Phased Array	Phased Array

FRINGE AREA: Orange on http://myswitch.digitalready.gov.au/

	Block A	Block B	Block C	Block D	Block E
Total Dipole length (mm)	740	273	254	237	222
Gain (dBi)	>10	>13	>13	>14	>14
Horizontal Polarisation	Phased Array	Phased Array	Phased Array	Phased Array	Phased Array
Vertical Polarisation	Yagi	Yagi	Yagi	Yagi	Yagi

Exceptions to above table:

- **Gosford NSW** and **Gold Coast Qld** requires blocks D and E to be horizontally polarised.
- **Bouddi** and **Wyong NSW** require blocks D and E to be vertically polarised.
- **Currumbin** and **Gold Coast Southern Hinterland Qld** require a unique antenna for channels 34, 35, 36, 37, 38, 39, 49, 50 with vertical polarisation.
- **Remote area towns** (excluding WA) receiving Imparja and Southern Cross Television from a local transmitter generally require a Block A antenna for the ABC transmitter out of town and another antenna pointed in town in a different channel block. A UHF/VHF diplexer can connect the antenna cables together to feed the receiver. SC

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PIC12F675-I/P	UHF Remote Switch (Jan09), Ultrasonic Cleaner (Aug10), Ultrasonic Anti-Ioaling (Sep10), Cricket/Frog (Jun12) Do Not Disturb (May13) IR-to-UHF Converter (Jul13), UHF-to-IR Converter (Jul13) PC Birdies *2 chips – $15 pair* (Aug13)	**PIC16F1587-I/P** Wideband Oxygen Sensor (Jun-Jul12)
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PIC16F88-I/P	Projector Speed (Apr11), Vox (Jun11), Ultrasonic Water Tank Level (Sep11), Quizzical (Oct11) Ultra LD Preamp (Nov11), 10-Channel Remote Control Receiver (Jan13), Revised 10-Channel Remote Control Receiver (Jul13), Nicad/NiMH Burp Charger (Mar14) **(NEW): Remote Mains Timer (Nov14)**	
PIC16LF88-I/P	Garbage Reminder (Jan13), Bellbird (Dec13)	
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PIC18F2550-I/SP	Batt Capacity Meter (Jun09), Intelligent Fan Controller (Jul10)	
PIC18F45K80	USB Power Monitor (Dec12)	
PIC18F4550-I/P	GPS Car Computer (Jan10), GPS Boat Computer (Oct10)	
PIC18F14K50	USB MIDIMate (Oct11)	
PIC18F27J53-I/SP	USB Data Logger (Dec10-Feb11)	
PIC18LF14K22	Digital Spirit Level (Aug11), G-Force Meter (Nov11)	
PIC18F1320-I/SO	Intelligent Dimmer (Apr09)	
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dsPIC33FJ128GP802-I/SP	Digital Audio Signal Generator (Mar-May10), Digital Lighting Controller (Oct-Dec10), SpotSync (May11), Digital Audio Delay (Dec11) Level (Sep11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12)	
dsPIC33FJ64MC802-E/P	Induction Motor Speed Controller (revised) (Aug13)	
dsPIC33FJ128GP306-I/PT	CLASSIC DAC (Feb-May 13)	
ATTiny961	VVA Thermometer/Thermostat (Mar10), Rudder Position Indicator (Jul11)	
ATTiny2313	Remote-Controlled Timer (Aug10)	
ATMega48-20AU	Stereo DAC (Sep-Nov09), RGB LED Strip Driver [**-20AU chip**] (May14)	

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PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
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WIDEBAND OXYGEN CONTROLLER MK2	JULY 2012	05106121	$20.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
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(for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above [Nov 2012/May 2013])			
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Vintage Radio

By Associate Professor Graham Parslow

STC's Type 500A 5-Valve Mantel Radio

STC's 1938 Type 500A is a well-made 5-valve mantel radio which was housed in a handsome timber cabinet. The unit featured here was obtained in quite good condition and required relatively little work to restore it to full operation.

This STC 1938 500B tombstone model still has it original speaker grille and knobs. Exactly the same grill and knobs would have been installed on the model 500A pictured above but these parts have been changed at some stage during the set's life.

THE 1938 STC Type 500A mantel radio is among the author's favourite radios. The attraction started with a visit to the palatial Como House (now a National Trust building) in Melbourne. One member of the wealthy family that previously lived in Como House was an avid radio listener and an STC Type 500A radio is displayed (in working condition) in her bedroom. It made a lasting impression on me at the time, well before radio collecting became a passion.

Some years later, the Type 500A radio featured here was offered on eBay and I duly purchased it (in 2006) for $300. Since then, it has occupied a prominent place in my home and has always been appreciated for its outstanding craftsmanship. STC's promotional material at the time stated that the "two-tone cabinet" was made from "specially selected highly-figured walnut veneers, hand rubbed" and with a "full piano finish".

I'm certainly not the only person to appreciate its qualities because my Type 500A radio came with an interesting story. It turned out that it had spent a long life of active service on a farm in the Illawarra region of NSW. When the farmer died, the radio was passed on to his son who kept it as a treasured memento before reluctantly deciding to sell it because he was moving to the US. We exchanged a number of pleasant emails during the transaction and when the radio arrived, I felt that I had inherited an obligation to get it going again and to look after it.

Prior modifications

In deference to its history, the radio hasn't been fully restored though. To keep the radio functional and "updated", the previous owner had had the knobs, speaker and speaker grille replaced at some stage, probably during the 1960s. The speaker is mounted on a baffle-board which is angled at 30° to the front face at one end of the cabinet. Its relatively easy to remove this to gain access to the grille material.

The speaker itself was originally an electrodynamic type and was plugged into a 5-pin socket on the rear of the

chassis. Two wires ran to the remotely-mounted output transformer, two were for the electromagnet and the fifth wire was an earth lead.

The speaker grille fabric had probably been replaced when the permanent-magnet loudspeaker was installed. This 'new' speaker was a Rola 6-inch (150mm) type H of 1950s vintage. It had been installed professionally, presumably by a local serviceman, and the work included adding a 2kΩ 20W resistor to replace the electromagnet in the HT filter circuit. The HT filter electrolytics (C10 & C11, both 8μF) were also replaced at the time.

The grille fabric and knobs originally used on the 500A were also used on the 1938 STC tombstone model 500B. This set is shown in one of the accompanying photos and is another of the author's prized radios. It's displayed next to the 500A and clearly demonstrates what the 500A's original grille fabric and knobs look like.

I've left my 500A just the way it came to me though, as I consider the replacements to be a genuine part of the radio's history.

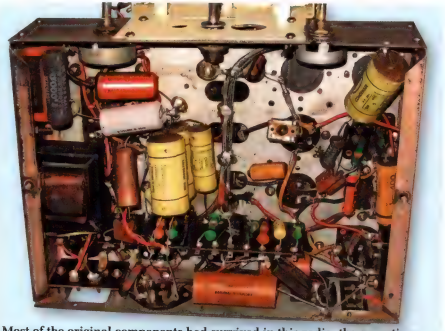
The chassis of the old Type 500A was in good order but required cleaning. The back-lit dial uses two 6.3V globes that shine through a green transparent sheet and a second opaque sheet with transparent station call-signs.

STC aimed high

STC stands for Standard Telephones and Cables and the company began life in London as International Western Electric in 1883. It became STC in 1925 when it was taken over by ITT of the USA. Two important high-points for the company involved supplying the radio systems for the *Queen Mary* and *Queen Elizabeth* ocean liners (1936-39) and patenting pulse code modulation (PCM) in 1938.

STC's Australian operations date from 1923 when Western Electric set up a manufacturing subsidiary in Sydney. Local manufacturing expanded significantly in 1936 following the construction of a new factory at 252-274 Botany Road, Alexandria, Sydney. This new factory employed some 700 people and was involved in building domestic radio receivers (such as the Type 500A), commercial transmitters and military equipment.

The sales motto for STC was "for tone it stands alone". All pre-war radios were high-specification models and this included both the cabinet work and the electronic circuitry. As a result, these radios were aimed at the higher end of the market and were relatively expensive. This changed after the war when the "Bantam" range of domestic radios was introduced to compete on price.



Most of the original components had survived in this radio, the exceptions being the loudspeaker, the output transformer, the celluloid dial cover, two 8μF HT filtering capacitors and two other coupling capacitors.

Circuit details

Fig.1 shows the circuit details of the STC Model 500A. The 'A' suffix describes the case type. On the other hand, the chassis is labelled 500-I and the 'I' defines the circuit used and its features.

For this particular circuit, the 1938 STC sales manual lists the features as including automatic volume control, tone control, a clearly marked tuning dial, a chromium dial escutcheon, an electromagnetic moving-coil loud-

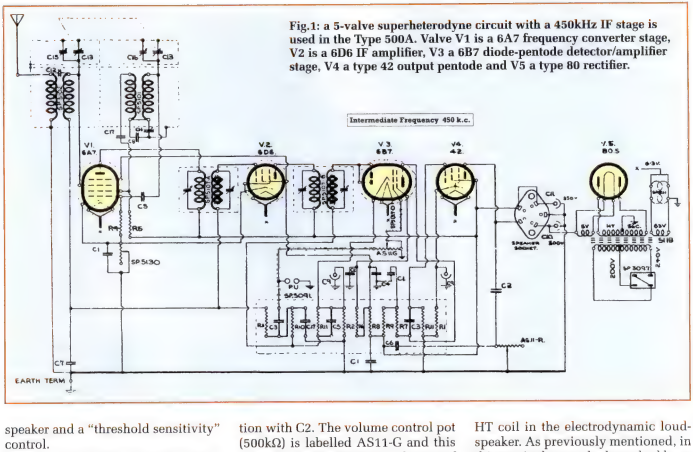


Fig.1: a 5-valve superheterodyne circuit with a 450kHz IF stage is used in the Type 500A. Valve V1 is a 6A7 frequency converter stage, V2 is a 6D6 IF amplifier, V3 a 6B7 diode-pentode detector/amplifier stage, V4 a type 42 output pentode and V5 a type 80 rectifier.

speaker and a "threshold sensitivity" control.

The circuit itself is a 5-valve superheterodyne type using a 450kHz IF stage. It includes a 6A7 frequency converter (V1), a 6D6 IF amplifier stage (V2), a 6B7 diode-pentode detector/amplifier stage (V3) and a type 42 pentode (V4) for the audio output. The 450kHz IF stage employs two metal dust core transformers and STC state that resistance coupling is used between the detector/amplifier (V3) and output stage (V4).

The last claim is a bit odd though, because C3 provides conventional capacitive coupling to the type 42 output pentode.

Potentiometer AS11-R (50kΩ) acts as a top-cut tone control in conjunction with C2. The volume control pot (500kΩ) is labelled AS11-G and this alters the gain of the 6B7. The top of the volume pot also accepts signals from a gramophone pick-up, with the signal fed in via terminals on the rear of the chassis (see photo).

The threshold sensitivity is adjusted by a trimpot marked as SP5130 on the circuit diagram and located at the lefthand rear of the chassis. This trimpot alters the RF gain of the 6A7 converter valve.

The final valve in the line-up is a type 80 rectifier. This provides full-wave rectification of the high-voltage secondary output of a conventional mains transformer to provide the HT line. This HT line is filtered by capacitors C10 & C11 (both 8μF) and the HT coil in the electrodynamic loudspeaker. As previously mentioned, in this particular set, the latter had been replaced by a 2kΩ 20W resistor.

The original twin-flex mains cord ran to a plug to the right of the speaker socket and this plug was used to select between a line voltage of 200VAC or 240VAC (see Fig.1). This warning label on the rear panel advises the user to check that the plug position correctly corresponds with the supply voltage .

Restoration

Despite the set's age, the cabinet was in good condition. It was polished with O-Cedar wood polish but was otherwise left unchanged. However, the celluloid dial window was nearly opaque due to oxidation.

The original celluloid was blow-moulded to clear the rather-stylish dial pointer which stands out from the back of the metal escutcheon. This means that a flat replacement window mounted behind the escutcheon would have fouled the pointer, so an alternative method had to be found.

Unfortunately, when I first acquired this radio I didn't have the skill to duplicate a blow-moulded window profile (although this is a technique that has subsequently been learnt). As a result, for this radio, a clear-plastic section was carefully cut from acetate sheet to fit the profile of the outer rim of the escutcheon. It was then carefully glued in using a few small dabs of super glue.

The result was agreeably satisfactory and allows the green back-lit dial to continue to impress more that 70 years after it was manufactured. The

Just arrived from the maker in London. "Cosmocord" De Luxe Crystal Pick-up, with incorporated Vol. Control. 18/6, Guaranteed 84/- value. Now 18/6.

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The STC Type 500A radio has pick-up terminals to accept the output from a record player. The pick-ups used in 1938 were either large magnetic types or piezo-electric crystals as shown in this advertisement from Levenson's Radio.

dial back-lighting is achieved using incandescent dial globes which shine through a layer of green backing positioned behind an opaque dial-plate with transparent call-signs.

Mains cord replacement

The original 2-core mains lead installed in the 1960s is now illegal in this type of equipment. In addition, this cord was terminated in a loose socket that made poor contact and this socket had to be orientated to match the mains voltage. This meant that the 200VAC tap on the power transformer could be incorrectly selected.

As a result, the 2-core mains lead was replaced with a modern 3-core lead which was directly connected to the 240VAC tap on the power transformer. This cord will be substituted with a cloth-covered cord in the near future, so that it is more in keeping with the set's age.

It is interesting to note that 2-core mains leads were common in 1938 and most radios, including this one, had no mains switch. This was because if a switch was installed, it was obligatory to switch the Active lead. However, many users spliced the power cord into a light bayonet socket using a 2-pin B-22 plug, so there was a random chance as to which lead would be the Active.

A DPDT switch would have overcome this problem but that would have added to the cost and users generally didn't demand this feature. Wall sockets were only sparsely installed during the 1930s but each room had a light, so double-adapting from the light fixture was fairly common. Users who wanted a switch had to install their own.

Dead on arrival

Although it appeared to be in reasonable (but dusty) condition, the radio was 'dead on arrival' (DOA) with no audio output. This was due to an open-circuit primary on the output transformer and this was quickly es-

The same punched chassis was used by STC for a range of radios and this explains the rather unusual use of a 3-gang tuning capacitor frame with one section missing. A 3-gang tuner would have been necessary in models with an additional tuned RF stage.

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This view shows the Type 500A after restoration. The new 3-core mains cord bypasses the voltage selection plug (to the right of the loudspeaker socket) and is wired directly to the transformer. It also allowed the chassis to be safely earthed.

tablished because there was no plate voltage on the type 42 output pentode. In addition, the cathode heater of this valve was glowing red but the valve itself remained cool.

The usual cause of a blown output transformer is excessive current through the output pentode (and thus the output transformer). This can be caused by changed resistor values in the grid bias circuit or failure of the audio coupling capacitor (C3 in this circuit), leading to a more positive grid than is healthy and increased power dissipation. It's also common to encounter both faulty resistors and a faulty capacitor together.

The pick-up terminals are on the rear of the chassis, directly above the antenna terminal. There's no provision to switch out the RF section when using the record player; instead, the user has to tune to a quiet spot on the dial, to avoid interference.

A replacement transformer was installed and the radio then performed perfectly. There is a quick way to check power dissipation in the output pentode and that is to simply remove it. With the 42 pentode in circuit, the power consumption is 51W and this drops to 38.5W after it's removed. A dissipation of 12.5W for the components associated with this stage is acceptable, so the stage appeared to be running normally. Importantly, the replacement output transformer wasn't running warm – they can get quite hot when excess current flows.

Nevertheless, true peace of mind required direct checking and the results were all good. First, the wirewound 400Ω cathode resistor was checked and its value found to be spot on. This resistor sets the grid bias voltage on the output pentode (the grid itself is tied to earth via R11, which holds the grid negative relative to the positive cathode). The cathode measured +11.7V with +223V on the anode plate.

Coupling capacitor C3 (0.01μF) was also checked. This was a Ducon replacement of 1960s manufacture and it measured OK. The fact that it was a replacement meant either that the original had failed or the repairman who had worked on the set had substituted it as a precaution.

The final check involved measuring the DC voltage across the output transformer's primary. This measured 15V DC while the DC resistance measured 600Ω, giving a calculated power dissipation of just 0.38W.

Pick-up terminals

The 500A's back panel features two screw terminals to accept the output from an external turntable pick-up (see the advertisement from Levenson's Radio). These two terminals connect to the volume control (AS11-G) in the first audio stage but note that there's no switch to switch the RF front-end out of circuit. Instead, the radio was tuned to a quiet part of the dial when the record player was being used.

In operation, the pick-up may have produced as much as 1V, so sensitivity wasn't a problem. It's worth noting that many valve radios included provision for a pick-up during the 1950s and even into the 1960s before portable transistor radios took over.

Finally, despite its age, this the radio still looks good and it still sounds good. It may not be completely original but it's still well worthwhile having in a collection. SC

PRODUCT SHOWCASE

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Running two video cameras for a car

I fitted a reversing camera that displays on my head unit and it always worked perfectly. I have recently added a front camera and that required the addition of a DPDT toggle on-off-on switch and two SPDT relays to allow me to view either camera on my head unit.

Sometimes the pictures from one or both cameras come on as monochrome and show tearing. Therefore, I am thinking that some sort of "glitches" are happening in the introduced circuitry that the head unit does not like. Both cameras are identical.

The video cable shielding seems to be effective as I see no evidence of interference when the picture is OK. Can you suggest a solution please? Please reply as if speaking to a 7-year old. Although I have successfully built several kit projects from your magazine, I don't really know how most of them work. (W. H., via email).

● We think you have incorrectly wired the power switch or relay connections. Make sure that power to each camera is fully disconnected when the other camera is powered. Either that or there is an intermittent short between the wires or connections that has both cameras on at the same time. This would cause the picture tearing and a black and white picture.

We are not sure if the cameras are wireless or simply wired to the display unit. If wired to the display using video leads, then these may have a poor shield connection.

Remote GSM monitoring

I am looking at building the GSM Remote Monitoring project (SILICON CHIP, March 2014) but I just had a thought and can't find an answer. Is the Arduino shield A-tick approved? I could not see any reference in your article or notice an A-Tick on the shield. If it's not approved, wouldn't that make anyone who made this project liable to legal action by ACMA? If not a legal project, shouldn't you have a disclaimer or warning about that in the article?

● The module used in the GSM Shield, SIM900 is GCF certified – see www.simcom.ee/modules/gsm-gprs/sim900/ Optus, Telstra and Vodafone Pacific are all members of GCC – see www.globalcertificationforum.org/members/operators/operator-members-list.html

So in theory at least, the SIM900 module should be OK to use on most Australian mobile networks. We are not sure whether the complete module requires separate certification. It's possible but almost all the mobile functions are provided by the SIM900 – the Arduino board basically just connects the antenna, I/O pins and power supply.

We think it's unlikely to cause serious interference. The only real variable is the power supply arrangement but given the radical difference in frequency between GSM (900MHz+) and the frequencies at which switchmode regulators operate (typically <2MHz) it is doubtful that this will have much of an effect.

If you have some programming experience and won't be using the device in a major city, you may want to consider using a 3G module rather than the

Speed Control For A 1-Horsepower Motor

I would like to build the Speed Controller for Universal Motors (SILICON CHIP, February 2014) but I am in the USA and we have 60Hz mains. Will the firmware still work correctly at this higher frequency? If not, is there a fix that would make it function properly at 60Hz?

Also, I am going to use the controller on a 1 HP, 180V DC, 5.3A permanent magnet motor with a 220VAC supply. Do you think it is possible to demagnetise the permanent magnets with the 23A current limit and/or the 10A average limit if the motor gets stalled? If so, what modifications would you recommend to the current limits? (S. G., via email).

● You do not need to change anything for 60Hz if you can use a 220VAC supply. The current in the 15V zener diode ZD1 will be a little higher but that is well within its limits.

However, if you did run it at 110V 60Hz, then the two 220nF 250VAC X2 capacitors would need to be increased to 330nF or 470nF to allow sufficient current flow for the 15V zener diode. In addition, the 10A rating will restrict its use to 1.1kW loads with a 110V supply.

Whether the magnets become demagnetised under stalled conditions depends on the design of the motor. Presumably, a properly designed motor would not lose magnetism when stalled (for a short period). In fact, the stall current could well be higher than 23A peak and 10A average when used directly from the mains rather than via the controller. So if the motor is not damaged when stalled and powered directly via the mains, it will not be damaged when using the controller.

The current levels driving a load in the controller are measured across a 0.01Ω 3W resistor. You could use a higher value such as 0.015Ω resistor to lower the current limit.

The firmware is not dependent on the mains frequency as the IGBT is switched on and off at 980Hz without synchronising to the mains frequency and so does not require changing for 60Hz mains. Finally, the outlet GPO would need to be changed to suit plugs for American power tools.

GSM one we specified but chances are the software would require changes. Apparently, 3G coverage outside cities is much better than 2G (GSM).

Do not attempt this though unless you are confident that you can successfully modify the software and debug it.

Headlight reminder for an Austin Healey

I want to build the Headlight Reminder from the August 2001 issue. Are the RR1500 wire links directional? Also I am fitting this to an Austin Healey which does not have door switches. I just want it to work on the headlights, so will I be able to leave some parts out? (I. W., via email).

● The door switch input does not need to be used but omitting that feature does not save on parts as the associated IC2b gate is within the IC2 4030 quad NOR gate package. Use the Door Switch Unused linking shown for LK3, LK4 & LK5.

The wire links (or 0Ω resistors) can be inserted in any direction; they are not polarised. The same comment applies to the resistors and these can go in with either orientation. The diodes, ICs and the electrolytic capacitors must be oriented correctly.

Burp charger hiccup

I have been trying to build the Burp Charger (SILICON CHIP, March 2014) and I seem to have got into all sorts of trouble. As best I can work out, if I shut things down by any means (kill the power source, turn the switch off, yank the thermistor plug), the Burp FET goes into thermal meltdown unless I first disconnect it from the battery.

The very first time I was sure it was working fine, I left it charging and when I returned hours later the Burp FET, its 0.1Ω resistor and the adjacent circuit board had all become engaged in a race to see who could produce the most smoke. I had thought I had built the (Jaycar) kit correctly.

I replaced IC3 and FET Q2 (with a IRF9540) and it seems to be working except for the shut-down thing and I obviously can't leave it like that. Plus why did it turn into smoke in the first place? I built a second one thinking that this would help me diagnose exactly what's gone wrong with the first one (I have a couple of crappy old chargers that could stand being replaced). Unfortunately, I seem to have ended up in the same place, except that I have cooked the PIC as well!

Any ideas? Is the specified SPP15P10 so different from the IRF9540 that it's never going to work properly? I remain impressed with your magazine and with "el burpo". (P. M., via email).

● You have discovered a flaw in our design – see the errata on page 101 of this issue. The two modifications listed there (adding a resistor and changing the power switch arrangement) should fix it. Q2 is an SPP15P10 as its on resistance is lower than the IRF9540, although this isn't critical and the IRF9540 will work as well.

ADSL modem reset box wanted

A really useful project would be an ADSL modem reset box. It would ping a couple of servers every 15 minutes. If there is no response, it cuts the power to the modem and re-tests after 10 minutes or so (some modems takes ages to boot).

So many weekends and night times I have been called in to restart a modem. There are a lot of people and readers with web applications nowadays. (B. H., via email).

● We suppose it would be useful if you have a flaky ADSL modem. A properly operating modem shouldn't need resetting as it should reconnect if there is a line failure.

In our own case, such a device wouldn't be very useful with our modem since usually we reset it because the connection has become slow rather than failed completely. It would be possible to include a speed test and reset it if the link is slow but that could give false triggers when the link is being heavily utilised and would also be annoying if it decided to reset the modem while you are in the middle of doing something.

Valiant Has A Reluctant Reluctor

I have a Valiant slant six with an earlier version of your electronic ignition. It has a reluctor distributor and I have to admit always having had trouble starting the thing. In recent times, the problem became much worse, to the point where the car just won't start. After three days (off and on) working on it, I am a defeated man.

I found there was no spark rather than a fuel issue and after checking the distributor pick up coil (280Ω) I decided it must be the old ignition module. And rather than look into it more deeply I decided it was time to buy your latest ignition project and dispense with the effort of finding the faulty part.

Alas, the new kit behaved the same so here I am with two units and no real progress but ever so much wiser. It turns out that nothing was actually wrong. It seems I am operating just on the triggering threshold of the pick-up coil pulse sensing circuitry.

What I found was that at cranking speed, the reluctor/pick-up coil only produces a pulse of around 0.3V and my testing seems to show that the ignition module needs more like 0.6V (minimum) to trigger a spark. So rather than spend $375 on a reconditioned distributor or $175 on a replacement Bosch pick-up coil that may or may not be any better I thought I'd see if you could help.

I'm hoping that there's a way to tweak the pick-up coil sensing circuitry and solve my problem once and for all. (R. L., Robina, NSW).

● The reluctor in your Valiant would seem to be faulty as it should provide several volts of signal rather than 0.3V, even at cranking speed. The reluctor trigger in the SILICON CHIP ignition system requires at least 0.6V to trigger. A lower threshold setting would tend to produce erratic firing.

Check the gap between the reluctor and its magnets on the distributor and adjust it so that you have the smallest possible gap but not so small that you run the risk of contact. The gap would need to allow for the temperature range of operation from a cold through to hot engine.

The reluctor may have a shorted turn but unfortunately, a resistance measurement will not necessarily reveal this as it will only reduce the resistance by a small amount (in a multi-turn coil).

USB Problem With The Micromite

I recently I purchased and put together your 44-pin Micromite kit (SILICON CHIP, August 2014). It all went together fine; even the soldering was simple enough to do as I have done SMD kits before. If I remember correctly the micro was still sealed in its carrier tape and I did wonder at the time as to just how it was programmed.

Anyhow, I had put it all together, checked all the soldered joints and powered it up via the laptop USB connection. The green power LED came on and I measured the voltages (3.3V and 5V appear correct). However, the laptop says "unknown USB device". I went to Device Manager, found the Unknown Device, right clicked it and selected update driver. After some time, it came back and told me that it has the latest drivers installed.

If that is so, why does it not recognise it? I am at a loss to know what to do next. I don't know if it the Micromite at fault or the computer set-up so where to from here? Can I confirm if it is the Micromite and has it been programmed? Or is it my laptop set-up?

I do recall I did also have a set up problem with the Freetronics USB-to-Serial interface module recently not recognising the USB device; it said the same thing (Unknown Device etc). I emailed them with my dilemma and they sent me a zip file with their driver and installation instructions and all is well; the laptop now recognises it. So where to next? (G. W., via email).

● The microcontrollers are programmed using a surface-mount IC socket on a programming adaptor board. The Micromite chip isn't responsible for the USB interface; the FT232RL chip (IC2) does that. It's possible that you lack drivers for this chip but that seems unlikely. However, try loading the drivers found here and see if that helps: www.ftdichip.com/Drivers/VCP.htm

If not, perhaps the USB chip isn't operating correctly. Carefully check the soldering of IC2 and CON3 with a magnifying glass in a good light. Also check that IC2's pin 1 dot is in the right place and that the 100nF capacitor above IC2 (C7) has good solder fillets between the ends of the capacitor and the PCB pads. Those are all the critical components for the USB function.

It probably depends on how many ADSL modems in use have this kind of failure mode; perhaps there are a significant number out there. It's a simple enough project so could be worthwhile. This could be done with a low-cost pre-built embedded module with Ethernet plus a mains-rated relay interface with suitable GPO sockets etc.

Siren for model radio-controlled boats

I would like to make a small electronic siren to install into a model police boat which I made and sometimes sail on a lake. I would also like to add a red and a blue flashing LED "police light". Do you have any suitable articles for making this? (B. D., via email).

● Perhaps the best solution is to use a couple of the projects sold by Jaycar in Short Circuits 2. One is a Hee-Haw siren (Jaycar Cat. KJ-8204 and instructions KJ-8205). This has a single flashing LED light. For two alternating LEDs that flash, use the KJ-8200 red/green flasher and KJ-8201 instructions and change the green LED to blue – see www.jaycar.com.au

Maximite USB driver problem

I am trying to install the USB driver for the Maximite but am getting an error message, to the effect that "Windows has found driver software for your device but encountered an error while attempting to install it". I have tried copies downloaded from your site and CircuitGizmo but both give the above error. Any thoughts? (R. W., via email).

● It does work and thousands of people have it running on Windows, Mac and Linux. For Windows, you must install the device driver and exactly follow each step in the notes provided with the driver. Most problems are caused by skipping or modifying a step. For Mac users, there are notes in the download section of the main Maximite web page.

If you are using Windows 8 you must instruct it to install "uncertified" drivers. The procedure is documented in this thread on the Back Shed forum: www.thebackshed.com/forum/forum_posts.asp?TID=5313&PN=1

Repairing Holden V8 ignition modules

I am having issues finding components to repair the ignition modules used by Holden on older V8 engines. These modules are becoming very rare and reconditioned units are also very expensive.

I have done extensive research online but I am still unable to discover which TO-3 transistor is used to switch the coil. Very few of these transistors have any markings at all, which makes them difficult to identify.

The transistor is a TO-3 type with three legs and is mounted in an alloy case which serves as a heatsink. The transistor is also fully insulated from the case. The bias or drive resistor looks like a 1W wirewound unit but its resistance is a mystery. I can only surmise that its value would be quite low as it does generate a fair amount of heat and I suspect that this is in part the reason for failure. The PCB under this resistor is also usually heat-damaged and discoloured.

Every failed unit I have seen has this resistor burnt out. The only unit I have seen with markings on the transistor has three sets of numbers: 21020, 507331 and 0304. I have been unable to find any kind of cross-reference which identifies the transistor from these numbers. Any help or advice would be greatly appreciated. (D. S., via email).

● The transistors are probably specifically made for the ignition which is probably a Bosch system. The transistors are probably no longer easy to obtain. The third lead of the transistor would be the collector, with the case isolated.

The MJ10012 is a TO-3 power transistor for ignition systems and could be used as a replacement. Its case needs to be isolated from the heatsink with an insulating washer and insulating bushes and the collector connection made via an eyelet, to the transistor case. This is a Darlington so the base

drive need only be 100mA to switch the transistor on.

Alternatively, we recommend our High Energy Ignition that uses an IGBT as the switching transistor, as published in November and December 2012 issues. This IGBT could also be used as a replacement transistor and the gate drive need only be via a 1kΩ resistor (that has little dissipation). The IGBT is an ISL9V5036P3-F085.

The MJ10012 is available from Jaycar Electronics (Cat ZT-2222) although the H version may suit your 3-leg requirements better. The IGBT is available from SILICON CHIP – see www.siliconchip.com.au/Shop/7 and search for the High Energy Ignition.

Circuit confusion with switching regulator

I recently purchased a Jaycar kit for the simple 1.5A Switching Regulator, but have yet to construct it (SILICON CHIP, February 2012). On checking the circuit diagram, I was confused by the orientation of the IRF9333 Mosfet (Q1) used to switch the regulator on. I recently received the EPE article photocopy, which is identical to the SILICON CHIP article.

My question is that being a P-channel Mosfet, the supply voltage at the drain connection should be negative with respect to the source connection, should it not? In this circuit, it is positive, ie, it is illustrated the wrong way round. The correct orientation is shown in the May 2012 Solar Panel Lighting Controller circuit diagram, where an IRF9540 P-channel power

Notes & Errata

Burp Charger for Nicad and NiMH Batteries, March 2014: disconnecting power using switch S1 allows current flow from the supply into IC3 and Mosfet Q2 via the 0.1Ω and 1kΩ resistors. This causes Q2 to switch on and so battery current flows through the 0.1Ω resistor.

This problem can be solved by removing S1 and bridging the two switch contact points on the PCB. Power is then switched either via the DC plug or at the input power source.

It is also recommended to connect a 100kΩ resistor between pins 6 & 7 of IC3b. This prevents a possible partial conduction of Q2 in an especially low switch-on threshold Mosfet. This resistor can be placed under the PCB across the terminals of the 100nF capacitor that also connects between pins 6 & 7 of IC3b.

Bistro Paging System, Circuit Notebook, October 2014: the column connections to the keypad are reversed, ie, the "star" key should be column 1 and pin 3 while the "hash" key should be column 3 and pin 5. The part number above the keypad is for the piezo buzzer not the keypad; the correct keypad number is Jaycar SP0770.

The part number (Jaycar AB3452) for the 400Hz buzzer was also omitted; this specifies the correct electromechanical or solid state style buzzer compatible with a micro output.

Mini 2 x 5W Stereo Amplifier . . . from p85

a while (up to about 30 seconds), simply because of the mass which needs to be heated. If it takes longer than 30 seconds then your iron may not have enough power. By the way, don't touch the IC or board during this procedure or immediately afterwards as it will be stinking hot!

It's then just a matter of soldering the remaining IC pins and cleaning up any bridges using solder wick. Refresh the joints on the first two pins you soldered, too. Adding flux paste is recommended for both procedures; when soldering the pins, it reduces the chance of bad joints. Clean off any excess flux using an appropriate solvent (metho will do in a pinch) and check the joints under magnification to ensure that solder has flowed properly onto every pin and pad.

Remaining SMDs

You can now proceed to fit all the smaller SMDs. Start with the two 3-pin SOT-23 packages. It's simply a matter of flowing a little solder onto one of the pads, heating that solder while sliding the device into place (using tweezers, for example), soldering the two remaining pads and then refreshing the solder on that first pad. Don't get the two devices mixed up.

If using the on-board power indicator LED, fit it now. First, you will need to check its orientation. Unfortunately, markings for SMD LEDs are not consistent. Some DMMs will light a LED in diode test mode, with the red lead indicating the anode but if your DMM won't light it in either direction, you may need to connect the LED to a 9V battery via a 1-10kΩ series resistor.

Orientate the LED so that the anode (positive) terminal goes to the pad marked "A" and then use a similar method as above to solder it in place. Try not to overheat it but do make sure that the solder has flowed properly onto the ends of the LED and the pads. Once again, flux paste is your friend.

Now proceed to fit all the surface-mount resistors and capacitors. Use the same method as described above. The resistors will have their values printed on top although you may need a magnifying glass to see them. The capacitors are unmarked, however the 10nF capacitors will be much slimmer than the 4.7μF types.

Through-hole parts

Dovetail two of the terminal blocks and fit these for CON4/CON5, with the wire entry holes facing the righthand edge of the board. Also fit terminal block CON3 with the wire entry at the bottom. If using the dual-gang log pot, it can go in now, otherwise solder the two mini horizontal trimpots in place.

You can now complete the assembly by fitting the two electrolytic capacitors (longer leads towards the "+" symbols at right), the RCA sockets and the pin header(s), if you require them.

Testing & use

There isn't much to testing the board. First, hook up an appropriate power supply with current metering (or connect a DMM in amps mode in series with one of the supply leads). Check that the quiescent current is less than 75mA and that LED1 lights.

It's then just a matter of turning down the volume control, hooking up a signal source and speakers and checking that the audio from both channels is clear and undistorted. SC

DIY Cruise Control Kit Wanted

Are you planning to release a automotive cruise control kit or circuit? I don't recall ever seeing one in your magazine and have surfed your website but could not see anything there. I know that many cars now have cruise control integrated in the engine management computer but there are vast numbers of cars that either don't have cruise control fitted or this was only available as an added cost option.

Commercial add-on units are available but even the cheapest of these are $300 or more and frankly, this seems grossly overpriced given the relative simplicity of the circuitry. It doesn't have to be adaptive, just a basic system to maintain road speed (although with the cheap proximity sensors available now it probably wouldn't add too much to the complexity or cost).

The inputs are already there for most cars built in the last 20 years: vehicle speed sensor signal, engine speed sensor and throttle position sensor. And with drive by wire, you don't even need mechanical actuators. Simplistically, you just compare the road speed with the set speed and output a voltage to the throttle potentiometer or a mechanical actuator like a vacuum or stepper motor.

Of course, there would be a few added safeguards like brake cut-out, clutch-cut out, over-rev cut-out etc. This is beyond my limited knowledge of electronics but should be a doddle for experts and probably most students. (E. F., via email).

● Cruise controls have been published in the distant past (in Electronics Australia) and that was when most cars had a similar throttle arrangement with a throttle cable actuating a carburettor valve. As you are aware, most cars now have fuel injection and many are "drive by wire".

The main problem with designing a cruise control is not with the electronics but with an effective and safe mechanical or electrical method of controlling the throttle that would be compatible for all vehicles. Every installation would be different, depending on brand and model of car. With these factors in mind, this is not a DIY project that could be successfully adapted to a wide range of cars.

Note that VDO in Australia do have cruise control kits but they differ between each make and model of vehicle and include the operating controls that match the existing steering stalk switches and all parts required to control the throttle.

Mosfet is used in the Q1 position.

In the switching regulator circuit, for the Simple Switcher, the Mosfet's internal reverse protection diode will conduct on switch-on, negating the purpose of the FET. (I. N., via email).

● The Mosfet is shown correctly. There's no requirement for the voltage at the drain of a P-channel Mosfet to be negative relative to its source (same applies with N-channel in reverse). This was explained in our Circuit Notebook pages in April 2012 and a similar (brief) explanation follows.

Mosfets are intrinsically a symmetrical device, ie, the drain and source are interchangeable and current can flow in either direction, controlled by the gate voltage. But they typically have an internal "parasitic" "body" diode. In an N-channel Mosfet, this has the anode at the source and cathode at the drain, whereas with a P-channel it's the opposite. As long as the Mosfet is arranged so that this body diode is reverse-biased, such that it prevents current from flowing when the Mosfet is off, then it will work.

In the case of the Simple Switcher, we want to stop current flowing if the supply polarity is incorrect. In this case, Q1's drain will be negative relative to its gate and source, so the body diode is reverse biased. So as long as the Mosfet channel is switched off (ie, gate voltage is not negative relative to source) then no current will flow. With the correct supply polarity, the body diode is forward biased but it is "shorted out" by the channel, which is switched on (gate below source), avoiding the voltage loss (and power dissipation) due to the diode's forward voltage.

In the case of the Solar Panel Lighting Controller, the Mosfet is being used to block current from flowing from diode D1 to L1 when it is off and hence the body diode connection is reversed compared to the Simple Switcher. In other words, we're using it to prevent current from flowing (or allowing it to flow) in the opposite direction and hence the diode must be orientated differently.

Incidentally, while most discrete Mosfets have three pins, a Mosfet is actually a 4-terminal device. The fourth pin is labelled "bulk" or "substrate". The control voltage is the gate-substrate voltage, the drain and source are interchangeable and there are two parasitic diodes, drain/substrate and source/substrate.

You can actually buy Mosfets like this (eg, BSS83) and they're typically used for analog switching. However, most of the time it's more convenient to have a 3-terminal device and so a typical Mosfet has the source connected to the substrate internally and thus it is no longer completely symmetrical. This also prevents the possibility of destruction through SCR latch-up.

How to tweak the Flexitimer

I recently built one of your Flexi/Interval Timers from the April 2010 issue of your magazine. The unit works great but I'm after some advice on how I can speed up the discharge of the circuit when the power is disconnected.

I apply power to the circuit and it switches the relay as required. When the unit times out and switches the relay back on (one-shot operation) I then have to turn it off and wait 45 seconds for the unit to discharge before I can run it again (it's operating my garage door remotely so I'm unable to use the restart circuit).

I'm after some advice on how I can discharge the unit quicker so that when the power is re-applied (within the 45-second period) it switches the relay and starts the count-down timer. The unit is powered by a 12V DC 1.5A plugpack. I have also changed resistor R3 from 100kΩ to 330kΩ. (D. B., via email).

● The 470µF supply bypass capacitor would be the culprit, holding up power to the circuit for 45 seconds. When using a 12V DC plugpack it is probably not necessary to have such a large bypass capacitor and a 10µF 16V capacitor should be suitable, to allow the supply to drop much faster.

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You could also speed up discharge of the supply capacitor by connecting a 1kΩ resistor across the supply on the cathode (K) side of diode D3 to 0V (GND), or directly across the capacitor.

Threshold voltage switch for fridge

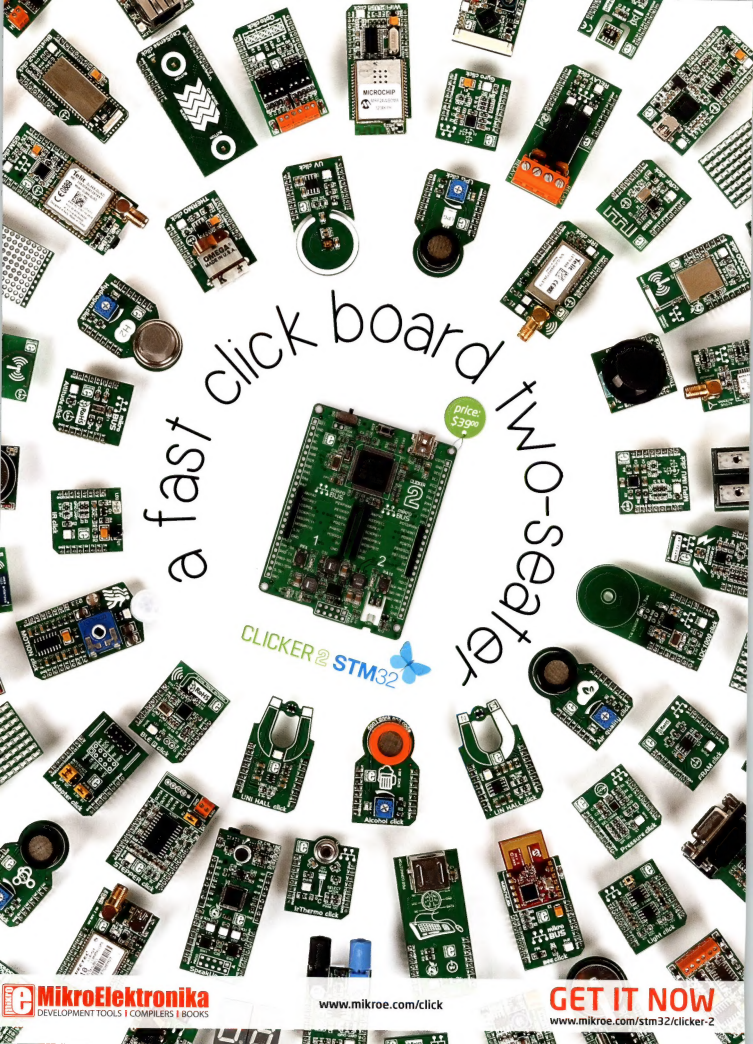
I built the Threshold Voltage Switch (SILICON CHIP, July 2014) and enjoyed building it. I have a solar panel on my van's roof, running an Engel fridge inside with an Allrounder 120Ah battery. The voltage varies quite a lot between day and night as it is hooked up to run permanently.

The fuse to run this fridge on DC is gold-plated as they want AS50 to replace it. I wonder if it would be possible to use your design without a lot of modifications to switch the power to the fridge off when a preset voltage of say 11.7V DC occurs?

This would save me replacing the fuse as the fridge cost is $A1000 in the first place. (P. M, Rochedale South, Qld).

- The Threshold Voltage Switch can be set to switch the relay at 11.7V. For a refrigerator, you would need a relay that can switch the necessary motor current. It seems some Engel fridges draw up to 4.2A but the peak current could be a lot higher.

The 30A relays mentioned on page 32 of the July 2014 article should be suitable. Whether the Threshold Voltage switch switches the relay on or off is dependent on LK3's position. VR3 adjusts the switching threshold. SC



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Max limited term discharge rate: (with <1000mAh battery)	150 Watts
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Max discharge rate:	40 amps (Battery dependent 100W continuous)
Min discharge voltage to maintain 30 amps:	0.9Volts (Battery dependent)
Min Voltage for 40 amp discharge:	2 volts at completion of test (Battery dependant)
Min discharge rate:	0.01 Amps

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*CBA IV does not have charging capabilities and will discharge batter during testing. Primary cells will be unusable after testing. MI recomme the CBA IV for batch testing of primary cells. Rechargeable cells will require recharging on a suitable charger shortly after testing.

#Optional accessories including probes, extended software and ampli are also available. Sold separately.

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